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Exploratory Investigation of
the Effect of Porous Surfaces on
Hypersonic Turbulent Boundary Layers

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SUMMARY

An exploratory investigation has been made with four different test surfaces to determine the effect of porous walls on the characteristics of a hypersonic turbulent flat-plate boundary layer. The investigation was an attempt to decrease the surface shear of the boundary layer by transmitting fluctuating pressure energy through the wall and absorbing it in a cavity beneath the wall. Pitot surveys were made at two locations, schlieren photographs of the boundary layer were taken, and hot-wire measurements in the flow above the boundary layer were made to determine whether the surfaces affected the turbulent boundary layer.

Neither an increase nor a decrease in surface shear or boundary-layer growth was detected. For the present test conditions, turbulence may be produced far enough away from the wall that alteration of the wall pressure field does not significantly affect the turbulence production. Also, the characteristic impedance of the test medium on the surface of the model was $1/300$ that of air at standard conditions, making most surfaces highly reflective to sound waves. Tabulations of the pitot data are included.

INTRODUCTION

Modification of the structure of turbulent boundary layers to decrease skin-friction drag is an interesting theoretical problem and also of great practical significance if successful. At Mach 8, the turbulent viscous drag of a configuration representative of a hypersonic transport is shown in reference 1 to be almost equal to the inviscid drag at flight Reynolds numbers. Even small decreases in drag would result in large fuel savings or a significant range increase.

In recent years, attempts have been made to reduce turbulent drag by a variety of methods. It is well known that the turbulent shear stress in liquid shear flows can be reduced by the addition of minute amounts of long-chain polymer liquids. (See ref. 2.) Such substances damp turbulence near the wall and thereby inhibit the production of turbulent shear stress. Three methods which have been tried to reduce skin friction in air flows are (1) the use of nonrigid surfaces (compliant walls) to absorb turbulent energy or to alter its production or decay - this method has been tried for both passive walls and driven walls (ref. 3); (2) the use of rigid, geometrically tailored walls to inhibit the production of turbulent shear energy (ref. 4); and (3) the use of external sources of sound energy directed into the boundary layer to alter the turbulence structure (ref. 5). Unfortunately, no repeatable consistent reduction in net drag has been realized by any method although drag reductions have been obtained in certain cases (ref. 4).

The present investigation was an attempt to reduce the surface shear of a hypersonic turbulent boundary layer by absorbing pressure fluctuation energy

transmitted through a porous wall. The rationale for conducting the test at hypersonic speeds was twofold: (1) the thick sublayer allowed the use of conventional materials without a roughness effect; and (2) the static pressure fluctuations relative to the mean static pressure become large at hypersonic speeds and may be more important to the turbulence-production process than at low speeds. A thick turbulent boundary layer on the surface of a sharp flat plate at 4° incidence to the flow (for which extensive measurements were reported in ref. 6) offered a suitable flow field in which a surface that was both porous and aerodynamically smooth could be tested. If the fluctuating surface pressure field in a turbulent boundary layer affects the cyclical bursting process in the wall layer as suggested in reference 7, then dissipation of the pressure field might decrease the bursting and tend to relaminarize the flow. Bursts may be responsible for the production of turbulence in the wall layer. (See ref. 8.)

At low speeds, porous surfaces used as acoustical treatment materials induce roughness effects. (See refs. 9 and 10.) These effects appear to be caused by two mechanisms: the inflow of the tangential shear flow at the surface into pore cavities (ref. 11), and the inflow and outflow of fluid through the pores (ref. 9) - an effect which is driven by the external turbulence. By sizing the pores to be less than the sublayer height, these effects should be minimized. For the present tests, the sublayer, although a fraction of the boundary-layer thickness, was about 1.4 mm thick and thereby made it possible to use commercially available porous materials for the test surfaces.

Four different porous materials were tested in addition to a solid reference surface. A cavity under the surface was either filled with various polyurethane foams having different sound absorbing properties or was left open. Changes in the surface shear near the end of the model were measured by surveying the boundary layer at two stations and calculating the change in momentum thickness with respect to surface distance. In addition, hot-wire measurements were made of the mass-flow fluctuations in a region of the shock layer influenced by the acoustic surfaces.

Identification of commercial products in this report is used to adequately describe the model. The identification of these commercial products does not constitute official endorsement, expressed or implied, of such products or manufacturers by the National Aeronautics and Space Administration.

SYMBOLS

c_f	local skin-friction coefficient
f	frequency, cps
M	Mach number
N_{Str}	Strouhal number, $2\pi f\delta^*/u_e$
p	pressure

R	Reynolds number
r_n	resistive acoustic impedance
T	temperature
u	velocity
u_τ	shear velocity
u^*	generalized velocity, $\int_0^u (\rho/\rho_w)^{1/2} du$
u^+	$= u^*/u_\tau$
x_n	reactive acoustic impedance
x,y	coordinates (see fig. 1)
y^+	$= y u_\tau \rho_w / \mu_w$
α_T	sound-power-transmission coefficient
δ	boundary-layer thickness
δ_D	thickness used in law of the wake (see eq. (5))
δ_v	velocity thickness of boundary layer
δ^*	displacement thickness of boundary layer
θ	momentum thickness of boundary layer
μ	viscosity
Π	constant in law of the wake (see eq. (5))
ρ	density
τ	shear stress

Subscripts:

e	edge value
t	total value
w	wall value
θ	based on momentum thickness

∞ free-stream value
 $(\sim)$ rms mean value

TUNNEL AND MODEL

Tests were conducted in the Mach 20 leg of the high Reynolds number helium tunnel complex described in reference 12. A previous study (ref. 6) of the turbulent boundary layer over the same model showed that model blockage did not affect the tunnel free-stream properties. For the present tests, the tunnel was operated at a nominal stagnation pressure of 13 790 kPa and a nominal total temperature of 291.7 K. The free-stream Mach number was 18.05 and the free-stream unit Reynolds number based on nominal stagnation conditions was 48.2×10^6 . Measured stagnation pressures, total temperatures, and unit Reynolds numbers varied slightly from run to run, about ± 1 percent, ± 5 percent, and ± 6 percent, respectively, from average conditions.

The model was a sharp flat plate (61 cm wide by 229 cm long) at 4° incidence to the flow with a leading-edge thickness of approximately 0.1 mm and a surface finish of 0.8 μ m rms. The model was made in three sections - a leading-edge section, a middle section, and an afterbody section. The afterbody (70.4 cm long) consisted of a base to which the upper test surfaces were attached, as shown in figure 1(b). An O-ring seal was used between the test surfaces and the afterbody base.

Porous upper surfaces were bonded to a backing plate containing 184 holes 4.45 cm in diameter and having an open porosity of 78 percent. The backing plate provided the necessary structural stiffness to the fragile screen and Feltmetal¹ surfaces while providing negligible resistance to sound waves.

INSTRUMENTATION AND DATA REDUCTION

Measured quantities of interest included pitot-pressure profiles, the pressure in the cavity of the model, tunnel stagnation conditions, and mass-flow fluctuations in the shock layer above the turbulent boundary layer. Each pitot survey comprised two runs, one covering the low-pressure region of the boundary layer between the surface and a height of 1.3 cm and the other covering from 1.3 cm to the outer edge of the boundary layer at about 5 cm. For the different surveys, different transducers and linear potentiometer calibrations were used.

The standard deviations for the linear potentiometer calibrations were 0.08 mm. Pitot pressures were measured with unbonded strain-gage transducers. For the low-pressure range from 2 kPa to 52 kPa, the standard deviation of the transducer calibration was 20.7 Pa. For the range between 52 kPa and 145 kPa, the standard deviation of the transducer calibration was 27.6 Pa.

¹Feltmetal: Registered trademark of Brunswick Corporation.

The pressure in the cavity (approximately 0.7 kPa) was measured with a 3.5-kPa strain-gage transducer having a calibration standard deviation of 4 Pa. The transducer was mounted in silicone rubber filler in the base of the afterbody (fig. 1(b)) to minimize the tubing length and thus minimize pressure lag effects. Tunnel stagnation pressures were measured with bonded strain-gage transducers that are accurate to within ± 69 kPa. Stagnation temperatures were measured with iron-constantan thermocouples having an accuracy of ± 2 percent of the reading. Before each run, a reference pressure measured by a secondary standard was recorded on each transducer to maintain accuracy in the data reduction.

It was not possible to measure the surface shear directly by mounting skin-friction balances in the porous surfaces; therefore, the gradient of the momentum thickness in the flow direction was used as a measure of the local skin-friction coefficient. The relation between $d\theta/dx$ and c_f (taken from ref. 13, page 252) is as follows:

$$\frac{d\theta}{dx} + \frac{\theta}{u_e} \frac{du_e}{dx} \left(2 + \frac{\delta^*}{\theta} - M_e^2 \right) = \frac{c_f}{2} \quad (1)$$

The velocity gradient at the edge was evaluated from pressures measured on the solid afterbody surface shown in figure 2. The value of $d(p/p_e)/dx$ on the afterbody was $-6.5 \times 10^{-4}/\text{cm}$, which contributed only about 3.6 percent to the local skin-friction coefficient through the second term of equation (1). Since the velocity-gradient term contributed little to the local skin-friction coefficient, a comparison of $d\theta/dx$ for different surfaces was assumed to give a valid indication of changes in surface shear subject, however, to errors in the measurement of θ .

Boundary-layer pitot profiles were reduced to Mach number profiles by using equation (16) of reference 14, with the assumption that the static pressure was constant throughout the boundary layer and equal to the measured wall or cavity pressure. Cavity pressures measured where the surveys were made (fig. 1(b)) are shown in figure 3. Mach number profiles were reduced to velocity and density profiles by using the Crocco relation as follows:

$$\frac{T_t - T_w}{T_{t,e} - T_w} = \frac{u}{u_e} \quad (2)$$

The edge of the boundary layer was found by using a method described in reference 15 that was based on the analogy between the outer part of the turbulent boundary layer and a wake flow. Experimentally determined values of $[1 - (u/u_e)]^{1/2}$ were plotted as a function of $y^{3/2}$, as shown in figure 4. Extrapolation of $[1 - (u/u_e)]^{1/2}$ to zero (i.e., $u/u_e = 1$) produced a value of y which was defined to be the edge of the boundary layer. Values of δ obtained by this method agreed well with the edge of the boundary layer estimated from pitot-pressure profiles.

It is characteristic of turbulent boundary layers at the present test conditions that the outer part of the boundary layer consist of a region in which significant changes occur in static temperature (and thus Mach number and pitot pressure) although changes in velocity are very small. Within the region of significant velocity change, the velocity profile is a power-law function of y , as for lower Mach number turbulent boundary layers. The thickness characterizing this region δ_v was found by plotting $\ln(u/u_e)$ as a function of $\ln(y)$ and extrapolating the linear portion of the profile to $u/u_e = 1$, as shown in figure 4(b). Values of δ_v found by this method were close to the $u/u_e = 0.995$ edge of the velocity boundary layer. Values of δ and δ_v , as well as edge conditions found by the method previously described, are included in table I. Pitot survey data are listed in table II.

Free-stream flow properties were calculated from the ideal gas relations of reference 14 by using the real gas correction factors of reference 16. In reference 16, the correction factors are applied to free-stream quantities calculated from the ideal gas relations by using measured stagnation pressures and temperatures. It was more convenient to correct the measured stagnation pressures and temperatures to an "equivalent" ideal gas state by using the appropriate correction factors from reference 16. Free-stream properties from the ideal gas relations using calculated equivalent ideal gas stagnation conditions are then correct. The correction factors were 5.8 percent for the stagnation pressure and 3.5 percent for the stagnation temperature.

SELECTION OF POROUS SURFACES AND BACKING MATERIALS

The purpose of the porous surfaces was to transmit turbulent pressure fluctuation energy into a backing material where it could be absorbed like sound energy is absorbed by acoustical blanket material. The experiment was designed around the possibility that removal of turbulent energy from the boundary layer might decrease the turbulent shear through a reduction in burst-producing surface-pressure fluctuations. Such an effect might appear as a reduction in surface shear and momentum loss. Since it was desirable that the surfaces be aerodynamically smooth in order to avoid roughness effects, the holes in the surface were constrained to be less than the thickness of the laminar sublayer, which for the present test conditions was about 1.4 mm.

In order to estimate the properties of surfaces which would be reasonable choices for transmitting pressure energy, knowledge of the rms fluctuating surface-pressure level and spectrum was required. The rms pressure level was estimated to be 6 times τ_w based on results presented in references 17 and 18. As shown in figure 5, the variation of τ_w over the afterbody was from 17 to 20 Pa. Using a mean value of 18.5 Pa for τ_w , $\tilde{p}_w$ was estimated to be 111 Pa rms. The free-stream value of $\tilde{p}_\infty$ from the data of reference 19 was 4.5 Pa rms. Power-spectral densities presented in references 20 and 21 for wall pressure fluctuations in supersonic flow show that above a Strouhal number of one, the power-spectral-density level decreases. Using the turbulent boundary-layer properties from reference 6, the frequency at $N_{Str} = 1$ was 13 kHz.

Estimates of the pressure energy transmission properties of various surfaces were made with a highly simplified model of the conditions at the surface of the model. Pressure fluctuations were assumed to be caused by a sound field consisting of plane waves in a stationary medium impinging normally on the surface. The medium was helium at the pressure and temperature existing at the surface of the model. With these assumptions, the characteristic impedance of the medium was 1.2 rayls ($1 \text{ rayl} = 1 \text{ N-sec/m}^3$). Due to the low characteristic impedance of this medium ($1/300$ that of air at standard conditions), surfaces which would be almost transparent to sound waves at standard ambient conditions were highly reflective at the assumed conditions.

Four different types of porous surface materials were tested: a fine-mesh screen, a sintered metal-fiber material, and two different types of perforated steel sheet. The screen was 200 mesh with a wire diameter of 0.05 mm, an overall thickness of 1.14 mm, and a measured rms surface roughness of 10 μm . The resistive component of the impedance was measured to be 14 rayls in the velocity range of 1 to 26 cm/sec. Assuming plane waves at normal incidence and $x_n \ll r_n$, the power transmission coefficient of the surface was 29 percent. (See ref. 22.) The sintered metal-fiber material, Feltmetal, had a measured surface roughness of 19 to 24 μm rms, and r_n was measured to be 12 rayls. The median pore size of the material was 500 μm . Its resistive component of impedance was slightly less than that of the screen; however, it was still 10 times that of helium at the static conditions existing on the model surface. Assuming $x_n \ll r_n$, the power-transmission coefficient for normal plane waves was 33 percent.

For perforated steel sheet, the impedance was calculated by the semiempirical method presented in the appendix of reference 23. Two different perforated sheet materials were used. One surface, designated P-1, had a hole diameter of 0.84 mm with a surface open porosity of 21 percent; the other surface, P-2, had a hole diameter of 1.14 mm with an open porosity of 37 percent. Both materials were 0.64 mm thick. The reactive part of the impedance is shown in figure 6 for frequencies from 10^2 to 10^5 Hz. The sound-power-transmission coefficient for the same frequency range is shown in figure 7.

The porous surfaces were selected to transmit a significant percent of pressure fluctuation energy while remaining aerodynamically smooth. Beneath the surface was a cavity that was constrained by model dimensions to be no more than 2.54 cm deep. The cavity was either left open or filled with an open pore polyurethane foam available in a range of thicknesses and pore sizes. Three sizes having 10, 30, and 80 pores per inch (ppi) were used. The void space was 97 percent, and the density was approximately 0.03 gm/cm^3 for all materials; however, the resistive pressure drop was an exponential function of the number of pores per inch.

At standard atmospheric conditions, the foam material behaves like a soft blanket, absorbent to incident sound waves in various degrees, depending on the material specific impedance and thickness. At the model test conditions, the material behaved in effect like an absorbing medium intermediate between a soft blanket and a rigid tile. (See ref. 24.) Inasmuch as the analysis of intermediate materials is not straightforward and the assumed sound wave model was highly simplified, no analysis of the backing material was made. Tests both

with and without the materials were made to determine whether any condition significantly affected the characteristics of the turbulent boundary layer.

RESULTS AND DISCUSSION

Schlieren photographs of the model with the end plates removed were taken to see if large changes could be observed in the turbulent boundary layer due to the effects of the porous surfaces. A schlieren photograph of the turbulent boundary layer over the rear portion of the model is shown in figure 8 with the various surfaces and test conditions noted. Above the model, the shock wave appears to be a broad band because of the interaction of the shock wave with the turbulent boundary layer on the tunnel wall. No distinct change in the boundary-layer structure can be seen for any surface, and the apparent thickness of the boundary layer is 4 cm in all cases. Some additional schlieren photographs not presented here were made for various surfaces backed with 10, 30, and 80 ppi foam. No change in the boundary-layer flow was noted, even for the most porous surface backed with different materials.

For each test surface, pitot surveys were made at two locations (2.54 cm apart) in order to determine the local skin-friction values. One location was 215.9 cm from the leading edge of the model, which corresponds to station 8 for the data of reference 6. The other location was 2.54 cm upstream of this point. Surveys farther upstream were not possible since it was found that probe interference effects caused the cavity pressure to increase as the probe approached the wall. The reason, as suggested in reference 25, was probably due to flow separation under the probe. In order to minimize both probe interference effects and streamwise corner effects due to the end plates, the upper surfaces were masked as shown in figure 9. With this arrangement, the cavity pressure did not increase as the probe approached the wall. Some preliminary surveys were made for materials backed with various foams; however, no change in boundary-layer characteristics was evident when the backing was changed. For this reason, the data presented here are for test surfaces with no backing material used in the model cavity.

Pitot profiles were reduced to incompressible generalized velocity profiles by using the following equation

$$u^* = \int (\rho/\rho_w)^{1/2} du \quad (3)$$

The resulting reduced profiles were compared with the law of the wall

$$u^+ = \frac{1}{k} \ln y^+ + C \quad (4)$$

where the constants k and C were found in reference 6 to be 0.43 and 5.5, respectively, for reduced hypersonic helium profiles. Figure 10(a) shows the data at station 213.4 for various surfaces, and figure 10(b) shows the data at

station 215.9. The shear velocities u_τ used to nondimensionalize the velocity profiles were calculated from the τ_w measurements (balance data) of reference 6 for the solid surface.

It is evident that the measured impermeable wall shear satisfactorily reduces the profiles to the incompressible law of the wall for all surfaces, from which it can be concluded that in no case was there a significant increase or decrease in the shear stress near the wall.

The outer part of the reduced profiles was examined in law-of-the-wake form (ref. 26)

$$\frac{u^* - u_e^*}{u_\tau} = \frac{1}{k} \ln (y/\delta_D) + \frac{\Pi}{k} (w - 2) \quad (5)$$

where $w = \ln(y/\delta_D)$ (from ref. 27) and $\Pi = \ln(dp/dx)$. In equation (5), δ is often used for δ_D to facilitate data reduction although the two thicknesses are usually slightly different. The errors involved in neglecting the difference in δ_D and δ are examined in reference 27. For the present data, δ was used for δ_D since relative differences between profiles were primarily of interest.

The data are shown in figure 11 at two different survey stations. Also shown in the figure is equation (5) with $k = 0.43$ and $\Pi = 0.55$. This value of Π was found in reference 26 to be characteristic of fully developed, zero-pressure-gradient turbulent flow. Figure 11 shows that for the outer layer, as for the near-wall data in figure 10, there are no significant differences between velocity profiles and thus no apparent effect of surface porosity.

An independent check on the value of c_f for different surfaces was made by plotting θ at the two survey locations, as shown in figure 12. For comparison purposes, $d\theta/dx$ from measured surface shear data and θ from the profile data of reference 6 at $x = 215.9$ cm are also shown. The data of the present test at $x = 213.4$ and 215.9 fall within ± 4 percent of a mean value and show no trend consistent with the local value of θ . That is, some surfaces produce large apparent $d\theta/dx$ although others show large negative $d\theta/dx$, but in all cases the level of θ is close to the solid surface value. It was concluded that the variations in slope were due to scatter in the data and could not be attributed to the effects of the surfaces on the flow.

Mean values of θ for the present data are consistently lower than for the data of reference 6, because of possible errors in the measurement of y near the wall, probe interference effects near the wall, and differences in the value of δ between the two tests. An error in y of 1 mm near the wall (greater than the estimated error for this test) would produce an error in θ of about 2 percent. Thus, the most probable causes of differences in θ between the two tests are probe interference effects and differences in the choice of δ . Figure 13 shows a typical function $(\rho u/\rho_e u_e)[1 - (u/u_e)]$, which was integrated over y to obtain θ . It is evident that probe interference effects near the wall could produce large errors in θ because of the steep slope of the function near $y = 0$.

Finally, hot-wire measurements of the mass-flow fluctuations in the shock layer were made to determine whether the surfaces significantly affected the radiated sound field. The hot wire, located as shown in figure 14, was in the flow field that was influenced by the boundary layer of the test surfaces. Measured values of $(\tilde{\rho u})/\rho u$ were converted to $\tilde{p}/p$ and were found to be within about ± 5 percent of the measured free-stream fluctuating pressures in reference 19. Since the free-stream sound level dominated the hot-wire measurements, it was concluded that the variations observed in measured sound pressure levels were probably within the experimental scatter of the data. The measured mean flow and pressure fluctuations are shown in the following table:

Surface	$(\tilde{\rho u}) / (\rho u)$	$\tilde{p}/p$
Solid	2.57×10^{-2}	3.60×10^{-2}
Feltmetal	2.78	3.89
P-1	2.47	3.46
Screen	2.78	3.89

CONCLUDING REMARKS

An investigation has been made on the effect of four porous surfaces on the characteristics of a hypersonic turbulent boundary layer. Schlieren photographs, pitot surveys of the boundary layer near the downstream end of the test surfaces, and hot-wire mass-flow fluctuations in the shock layer above the boundary layer were made to determine whether the surfaces changed the boundary layer. The surfaces tested showed neither a decrease nor an increase in the skin-friction drag of the boundary layer when examined by several methods.

It is possible that, for the present test conditions, turbulence is produced far enough away from the wall that changes in the pressure field at the wall do not significantly affect the turbulence production. Also, the characteristic impedance of the assumed test medium on the surface of the model was approximately 1/300 that of air at standard conditions. The surfaces were reflective to sound waves, and the simple acoustical model used to estimate the ability of the surfaces to transmit sound waves may not be realistic for hypersonic flow. Therefore, the experiment does not prove that sound and pseudo-sound absorbing surfaces cannot reduce turbulent activity; it only proves that the surfaces used in the present experiment did not seem to have such an effect for the limited spatial extent of the treated surface.

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REFERENCES

1. Penland, J. A.; and Romeo, D. J.: Advances in Hypersonic Exploration Capability - Wind Tunnel to Flight Reynolds Number. *J. Aircr.*, vol. 8, no. 11, Nov. 1971, pp. 881-884.
2. Wu, Jin: Suppressed Diffusion of Drag-Reducing Polymer in a Turbulent Boundary Layer. *J. Hydronaut.*, vol. 6, no. 1, Jan. 1972, pp. 46-50.
3. Bushnell, Dennis M.; Hefner, Jerry N.; and Ash, Robert L.: Effect of Compliant Wall Motion on Turbulent Boundary Layers. *Phys. Fluids*, vol. 20, no. 10, pt. II, Oct. 1977, pp. S31-S48.
4. Balasubramanian, R.; Cary, A. M., Jr.; Bushnell, D. M.; and Ash, R. L.: Influence of Transverse Surface Waves on Turbulent Boundary Layers. NASA Paper presented at Fifth Biennial Symposium on Turbulence (Rolla, Missouri), Oct. 1977.
5. Gougat, P.: External Sound Field Effect on a Turbulent Boundary Layer. NASA TT F-15,841, 1974.
6. Watson, Ralph D.: Characteristics of Mach 10 Transitional and Turbulent Boundary Layers. NASA TP-1243, 1978.
7. Offen, G. R.; and Kline, S. J.: Combined Dye-Streak and Hydrogen-Bubble Visual Observations of a Turbulent Boundary Layer. *J. Fluid Mech.*, vol. 62, pt. 2, Jan. 23, 1974, pp. 223-239.
8. Kim, H. T.; Kline, S. J.; and Reynolds, W. C.: The Production of Turbulence Near a Smooth Wall in a Turbulent Boundary Layer. *J. Fluid Mech.*, vol. 50, pt. 1, Nov. 15, 1971, pp. 133-160.
9. Boldman, Donald R.; and Brinich, Paul F.: Skin Friction on a Flat Perforated Acoustic Liner. *AIAA J.*, vol. 14, no. 11, Nov. 1976, pp. 1656-1659.
10. Roberts, D. W.: Equivalent Sand-Grain Roughness of Perforated Plate Acoustic Linings. AIAA Paper 77-104, Jan. 1977.
11. Nestler, D. E.: Static Pressure Port Errors in Hypersonic Turbulent Flow. AIAA Paper No. 71-270, Mar. 1971.
12. Watson, Ralph D.; and Bushnell, Dennis M.: Calibration of the Langley Mach 20 High Reynolds Number Helium Tunnel Including Diffuser Measurements. NASA TM X-2353, 1971.
13. Pai, Shih-I: Viscous Flow Theory. I - Laminar Flow. D. Van Nostrand Co., Inc., c.1956.
14. Mueller, James N.: Equations, Tables, and Figures for Use in the Analysis of Helium Flow at Supersonic and Hypersonic Speeds. NACA TN 4063, 1957.

15. Peterson, John B., Jr.: Boundary-Layer Velocity Profiles Downstream of Three-Dimensional Transition Trips on a Flat Plate at Mach 3 and 4. NASA TN D-5523, 1969.
16. Erickson, Wayne D.: Real-Gas Correction Factors for Hypersonic Flow Parameters in Helium. NASA TN D-462, 1960.
17. Lilley, G. M.: Wall Pressure Fluctuations Under Turbulent Boundary Layers at Subsonic and Supersonic Speeds. AGARD Rep. 454, Apr. 1963.
18. Kistler, A. L.; and Chen, W. S.: The Fluctuating Pressure Field in a Supersonic Turbulent Boundary Layer. Tech. Rep. No. 32-277 (Contract No. NAS 7-100), Jet Propul. Lab., California Inst. Technol., Aug. 15, 1962.
19. Fischer, M. C.; and Wagner, R. D.: Transition and Hot-Wire Measurements in Hypersonic Helium Flow. AIAA J., vol. 10, no. 10, Oct. 1972, pp. 1326-1332.
20. Pate, S. R.; and Brown, M. D.: Acoustic Measurements in Supersonic Transitional Boundary Layers. AEDC-TR-69-182. U.S. Air Force, Oct. 1969. (Available from DDC as AD 694 071.)
21. Bies, David Alan: A Review of Flight and Wind Tunnel Measurements of Boundary Layer Pressure Fluctuations and Induced Structural Response. NASA CR-626, 1966.
22. Kinsler, Lawrence E.; and Frey, Austin R.: Fundamentals of Acoustics. Second ed., John Wiley & Sons, Inc., c.1962.
23. Mariano, S.: Effect of Wall Shear Layers on the Sound Attenuation in Acoustically Lined Rectangular Ducts. J. Sound & Vib., vol. 19, no. 3, Dec. 8, 1971, pp. 261-275.
24. Beranek, Leo L.: Acoustical Properties of Homogeneous, Isotropic Rigid Tiles and Flexible Blankets. J. Acoustical Soc. America, vol. 19, no. 4, pt. 1, July 1947, pp. 556-568.
25. Morkovin, M. V.; and Bradfield, W. S.: Probe Interference in Measurements in Supersonic Laminar Boundary Layers. J. Aeronaut. Sci., vol. 21, no. 11, Nov. 1954, pp. 785-787.
26. Coles, Donald: The Law of the Wake in the Turbulent Boundary Layer. J. Fluid Mech., vol. 1, pt. 2, July 1956, pp. 191-226.
27. Bull, M. K.: Velocity Profiles of Turbulent Boundary Layers. Aeronaut. J. R. Aeronaut. Soc., vol. 73, no. 698, Feb. 1969, pp. 143-147.

TABLE I.- EDGE AND INTEGRAL BOUNDARY-LAYER PROPERTIES

Surface	x, cm	Test	Runs	M _e	R _e , per meter	δ, cm	δ _v , cm	δ*, cm	θ	R _θ
Solid	213.4	45	18,22	11.49	63.4 × 10 ⁶	5.13	2.48	2.47	2.52 × 10 ⁻²	15 936
Feltmetal	213.4	45	17,23	11.19	58.9	5.47	2.51	2.38	2.52	14 802
P-1	213.4	45	19,24	11.42	62.3	5.04	2.29	2.49	2.59	16 100
P-2	213.4	45	16,25	11.33	62.8	5.18	2.41	2.51	2.59	16 241
Screen	213.4	45	20,21	11.61	63.2	5.19	2.39	2.51	2.58	16 300
Solid	215.9	44	2,33	11.58	63.3	5.24	2.39	2.48	2.50	15 835
Feltmetal	215.9	44	9,35	11.46	61.3	4.80	2.27	2.41	2.49	15 255
P-1	215.9	44	14,31	11.44	63.6	5.27	2.29	2.42	2.48	15 766
P-2	215.9	44	4,36	11.31	59.6	4.98	2.41	2.46	2.60	15 456
Screen	215.9	44	7,30	11.67	65.5	5.02	2.34	2.38	2.39	15 646

TABLE II.- PITOT SURVEY DATA

(a) Summary of test conditions

Surface	x, cm	Test	Runs	P _t , kPa (a)	T _t , K	T _w /T _t	R _∞ , per meter
Solid	213.4	45	18	1.358×10^4	294.3	0.973	4.640×10^7
	213.4	45	22	1.348	279.3	1.008	4.952
Feltmetal	213.4	45	20	1.333	301.5	.953	4.403
	213.4	45	21	1.353	288.7	.981	4.745
P-1	213.4	45	17	1.356	289.3	.985	4.744
	213.4	45	23	1.350	284.8	.989	4.825
P-2	213.4	45	19	1.344	300.4	.954	4.464
	213.4	45	24	1.344	285.4	.988	4.793
Screen	213.4	45	16	1.360	292.1	.972	4.696
	213.4	45	25	1.348	285.9	.991	4.792
Solid	215.9	44	2	1.358	299.8	.988	4.522
	215.9	44	33	1.348	291.5	.976	4.666
Feltmetal	215.9	44	7	1.340	297.6	.970	4.506
	215.9	44	30	1.331	283.7	.987	4.782
P-1	215.9	44	9	1.343	300.4	.963	4.460
	215.9	44	35	1.362	292.6	.974	4.689
P-2	215.9	44	14	1.364	287.6	.994	4.809
	215.9	44	31	1.344	290.9	.980	4.666
Screen	215.9	44	4	1.358	307.6	.951	4.365
	215.9	44	36	1.362	297.6	.960	4.582

^aData listings corrected to p_t = 13 790 kPa.

TABLE II.- Continued

(b) Data listing

y, cm	Pitot pressure, kPa	y, cm	Pitot pressure, kPa	y, cm	Pitot pressure, kPa
5.392	141.708	3.914	135.097	2.237	49.532
5.382	141.941	3.891	134.981	2.202	48.205
5.375	142.313	3.873	134.725	2.151	45.435
5.368	142.476	3.846	134.539	2.088	42.688
5.363	142.523	3.806	133.631	2.020	39.546
5.359	142.523	3.752	131.582	1.957	36.846
5.354	142.476	3.687	129.511	1.908	35.100
5.336	142.453	3.618	127.765	1.878	34.076
5.303	142.523	3.560	126.043	1.861	33.494
5.253	142.406	3.518	125.205	1.846	33.261
5.198	142.290	3.492	124.623	1.818	32.586
5.154	142.104	3.474	123.599	1.774	31.073
5.124	142.010	3.451	122.644	1.714	29.141
5.104	142.173	3.414	121.760	1.646	27.209
5.088	142.453	3.361	119.595	1.577	25.114
5.069	142.592	3.299	116.034	1.524	23.485
5.034	142.569	3.230	111.052		
4.983	142.499	3.165	106.839		
4.921	142.383	3.115	103.674		
4.853	142.104	3.084	101.858		
4.790	141.592	3.064	101.672		
4.744	141.312	3.046	101.183		
4.714	141.126	3.015	98.879		
4.692	141.196	2.970	95.434		
4.671	140.963	2.911	91.081		
4.637	140.660	2.843	86.425		
4.589	140.358	2.777	81.305		
4.528	139.869	2.721	77.720		
4.458	139.403	2.687	75.439		
4.393	138.938	2.664	74.275		
4.344	138.798	2.548	72.878		
4.310	139.031	2.624	71.109		
4.289	138.915	2.585	68.782		
4.271	138.752	2.530	65.313		
4.243	138.635	2.466	61.217		
4.200	138.053	2.397	56.747		
4.142	137.169	2.339	53.070		
4.075	136.424	2.298	51.324		
4.005	135.889	2.271	50.509		
3.952	135.283	2.255	50.067		

TEST 45
RUN 22

TABLE II.- Continued

(b) Continued

y, cm	Pitot pressure, kPa	y, cm	Pitot pressure, kPa	y, cm	Pitot pressure, kPa
1.467	22.064	.974	12.348	.377	5.976
1.458	21.688	.952	12.126	.362	5.769
1.454	21.358	.933	11.873	.352	5.631
1.451	21.121	.921	11.605	.347	5.577
1.447	21.013	.913	11.543	.344	5.547
1.438	20.937	.909	11.566	.340	5.516
1.421	20.752	.905	11.543	.331	5.501
1.399	20.262	.900	11.467	.314	5.370
1.377	19.786	.886	11.367	.291	5.110
1.360	19.104	.865	11.167	.269	4.880
1.349	18.621	.842	10.937	.252	4.734
1.342	18.460	.822	10.761	.240	4.619
1.338	18.375	.808	10.577	.234	4.481
1.334	18.460	.781	10.209	.231	4.404
1.328	18.536	.763	9.979	.228	4.351
1.314	18.329	.741	9.757	.223	4.328
1.293	17.747	.720	9.542	.210	4.197
1.271	17.287	.704	9.358	.197	4.036
1.253	17.141	.694	9.212	.187	3.868
1.242	16.957	.688	9.174	.182	3.722
1.235	16.773	.685	9.105	.179	3.683
1.232	16.443	.681	8.974		
1.229	16.366	.674	8.806		
1.224	16.198	.659	8.645		
1.210	16.136	.637	8.453		
1.189	15.830	.616	8.300		
1.168	15.293	.599	8.139		
1.148	14.802	.587	8.008		
1.135	14.541	.580	7.893		
1.110	14.273	.577	7.840		
1.093	13.997	.575	7.763		
1.071	13.629	.570	7.717		
1.052	13.261	.556	7.610		
1.038	12.954	.535	7.387		
1.029	12.778	.512	7.180		
1.025	12.678	.494	7.034		
1.021	12.617	.481	6.904		
1.018	12.548	.444	6.613		
1.011	12.586	.423	6.444		
.996	12.548	.399	6.214		

TEST 45
RUN 20

TABLE II.- Continued

(b) Continued

Y, cm	Pitot pressure, kPa	Y, cm	Pitot pressure, kPa
5.240	143.239	3.161	103.525
5.229	143.429	3.144	103.051
5.201	143.500	3.118	101.817
5.155	143.595	3.074	99.445
5.095	143.547	3.015	95.839
5.029	143.239	2.950	92.090
4.969	143.073	2.881	86.966
4.928	143.049	2.826	81.462
4.899	142.812	2.788	79.398
4.879	142.812	2.767	78.710
4.852	142.859	2.750	77.619
4.809	142.765	2.725	75.863
4.752	142.527	2.683	73.325
4.684	142.361	2.629	69.885
4.612	141.934	2.563	65.757
4.544	141.365	2.493	62.008
4.493	140.724	2.431	58.426
4.461	140.155	2.390	55.816
4.440	140.036	2.363	54.654
4.205	138.470	2.348	53.871
4.134	137.972	2.328	52.827
4.079	137.901	2.293	51.261
4.043	137.284	2.242	48.818
4.020	137.047	2.178	45.283
4.001	136.976	2.107	41.795
3.973	136.834	2.040	39.186
3.928	136.715	1.990	37.454
3.870	135.885	1.960	36.339
3.802	134.343	1.941	35.675
3.730	132.184	1.924	35.509
3.667	130.025	1.896	34.655
3.624	128.222	1.851	33.160
3.597	127.012	1.790	31.191
3.577	126.561	1.720	29.103
3.553	126.087	1.650	26.826
3.394	118.637	1.594	24.857
3.323	114.486	1.559	23.504
3.258	109.931	1.538	22.816
3.210	107.416	1.522	22.698
3.180	105.186	1.500	22.105

TEST 45
RUN 21

TABLE II.- Continued

(b) Continued

y, cm	Pitot pressure, kPa	y, cm	Pitot pressure, kPa	y, cm	Pitot pressure, kPa
1.489	21.496	.982	11.715	.482	6.175
1.476	21.037	.968	11.493	.479	6.168
1.460	20.693	.959	11.325	.475	6.129
1.448	20.464	.954	11.203	.463	6.076
1.438	20.265	.951	11.180	.445	5.954
1.433	20.105	.946	11.096	.422	5.770
1.430	19.845	.934	10.989	.402	5.572
1.427	19.623	.913	10.844	.385	5.388
1.423	19.448	.890	10.607	.376	5.258
1.410	19.226	.869	10.263	.369	5.167
1.391	18.951	.855	9.935	.366	5.113
1.369	18.699	.843	9.759	.361	5.083
1.351	18.462	.837	9.621	.350	5.021
1.338	18.164	.835	9.522	.330	4.884
1.330	17.835	.831	9.438	.305	4.708
1.325	17.476	.821	9.384	.280	4.471
1.322	17.285	.801	9.285	.260	4.227
1.316	17.033	.775	9.239	.246	4.051
1.301	16.926	.751	9.079	.239	3.898
1.279	16.743	.734	8.895	.235	3.799
1.254	16.292	.724	8.766	.233	3.715
1.231	15.872	.717	8.682	.226	3.654
1.214	15.627	.713	8.590	.212	3.516
1.203	15.474	.709	8.521	.191	3.302
1.197	15.375	.701	8.437	.166	3.004
1.193	15.352	.685	8.338	.145	2.706
1.190	15.276	.663	8.124	.131	2.385
1.181	15.123	.640	7.849	.122	2.156
1.163	14.825	.621	7.627	.117	2.003
1.140	14.450	.609	7.528	.114	1.912
1.115	14.114	.601	7.421	.110	1.828
1.096	13.801	.597	7.344	.099	1.774
1.083	13.404	.594	7.306	.082	1.698
1.075	13.228	.588	7.268	.067	1.591
1.070	13.228	.575	7.199	.057	1.507
1.068	13.190	.554	7.062	.052	1.461
1.060	12.999	.530	6.878	.049	1.423
1.045	12.708	.510	6.634		
1.023	12.342	.496	6.435		
1.000	12.013	.487	6.252		

TEST 45
RUN 17

TABLE II.- Continued

(b) Continued

y, cm	Pitot pressure, kPa	y, cm	Pitot pressure, kPa	y, cm	Pitot pressure, kPa
5.359	143.297	3.785	132.410	2.066	39.599
5.356	143.554	3.757	131.314	2.004	37.361
5.353	143.880	3.713	129.775	1.936	34.377
5.350	144.230	3.656	128.540	1.873	31.696
5.338	144.276	3.589	126.815	1.825	29.714
5.309	144.253	3.520	123.854	1.795	28.991
5.265	144.067	3.460	121.243	1.777	28.198
5.208	143.437	3.419	120.240	1.760	27.779
5.148	142.668	3.394	120.147	1.732	27.219
5.097	142.365	3.377	119.587	1.685	26.077
5.062	142.505	3.354	118.282	1.628	24.375
5.038	142.435	3.316	115.647		
5.019	142.505	3.263	111.544		
4.987	142.481	3.200	106.905		
4.941	142.528	3.131	102.545		
4.883	142.225	3.065	99.328		
4.818	141.642	3.018	96.251		
4.748	141.246	2.988	93.383		
4.690	140.943	2.969	92.031		
4.651	140.686	2.952	92.077		
4.627	140.593	2.922	90.422		
4.607	140.849	2.876	87.788		
4.585	140.873	2.818	83.521		
4.549	140.709	2.750	77.763		
4.496	140.243	2.683	71.865		
4.435	139.707	2.632	68.018		
4.365	139.217	2.596	65.966		
4.302	138.588	2.575	64.661		
4.257	137.772	2.559	63.938		
4.228	137.702	2.536	62.260		
4.208	137.702	2.495	59.345		
4.189	137.492	2.441	55.965		
4.156	137.352	2.377	52.048		
4.111	137.212	2.310	48.831		
4.051	136.606	2.252	46.313		
3.984	135.720	2.212	44.821		
3.917	134.648	2.186	43.352		
3.863	134.042	2.170	42.630		
3.828	133.272	2.151	41.884		
3.805	132.853	2.117	41.091		

TEST 45
RUN 23

TABLE II.- Continued

(b) Continued

Y, cm	Pitot pressure, kPa	Y, cm	Pitot pressure, kPa	Y, cm	Pitot pressure, kPa
1.618	23.987	1.134	13.459	.533	6.637
1.601	23.237	1.118	13.283	.513	6.491
1.588	22.900	1.095	13.091	.490	6.292
1.561	23.091	1.073	12.854	.469	6.093
1.545	22.425	1.054	12.770	.453	5.909
1.525	21.889	1.040	12.609	.443	5.802
1.506	21.215	1.032	12.402	.437	5.771
1.491	20.771	1.028	12.226	.433	5.764
1.480	20.618	1.026	11.996	.429	5.748
1.474	20.587	1.021	11.736	.420	5.695
1.471	20.633	1.008	11.568	.402	5.503
1.468	20.511	.988	11.284	.380	5.251
1.463	20.082	.963	10.978	.358	5.059
1.449	19.584	.942	10.787	.341	4.937
1.427	18.972	.927	10.741	.330	4.814
1.406	18.551	.892	10.725	.323	4.745
1.388	18.390	.872	10.534	.320	4.699
1.376	18.359	.850	10.220	.316	4.638
1.370	18.191	.829	9.883	.310	4.554
1.367	17.999	.813	9.707	.296	4.409
1.364	17.770	.802	9.577	.275	4.217
1.360	17.639	.795	9.500	.254	4.026
1.347	17.417	.792	9.477	.239	3.850
1.328	17.157	.788	9.431	.229	3.696
1.306	16.736	.777	9.232	.225	3.620
1.288	16.391	.759	8.972	.223	3.566
1.274	16.192	.736	8.735		
1.266	16.024	.714	8.528		
1.260	15.656	.695	8.252		
1.256	15.626	.683	8.046		
1.252	15.618	.675	7.946		
1.242	15.411	.671	7.923		
1.224	15.090	.668	8.030		
1.202	14.799	.660	8.122		
1.181	14.439	.644	7.969		
1.166	14.041	.622	7.640		
1.155	13.696	.599	7.234		
1.149	13.551	.580	7.004		
1.144	13.558	.566	6.866		
1.141	13.528	.558	6.790		

TEST 45
RUN 19

TABLE II.- Continued

(b) Continued

y, cm	Pitot pressure, kPa	y, cm	Pitot pressure, kPa
5.094	142.875	3.262	111.506
5.036	142.993	3.218	108.872
4.974	142.804	3.190	107.931
4.924	142.546	3.172	106.850
4.887	142.381	3.149	106.144
4.864	142.452	3.113	104.075
4.846	142.569	3.060	100.853
4.821	142.593	2.997	96.197
4.781	142.240	2.928	90.695
4.726	142.052	2.862	85.215
4.662	141.911	2.811	81.641
4.593	141.605	2.780	79.360
4.532	140.994	2.759	78.819
4.489	140.523	2.742	78.231
4.461	140.194	2.713	76.280
4.441	140.100	2.667	73.787
4.419	139.983	2.610	69.813
4.383	139.606	2.544	65.909
4.330	139.160	2.476	61.583
4.269	138.525	2.420	57.820
4.200	138.101	2.384	55.422
4.133	137.749	2.362	54.646
4.083	137.537	2.345	54.505
4.050	137.631	2.321	53.070
4.028	137.560	2.282	50.624
4.009	137.090	2.227	48.132
3.977	136.620	2.161	45.639
3.928	136.173	2.092	42.559
3.868	135.350	2.032	39.713
3.800	133.069	1.989	38.114
3.729	130.294	1.962	37.550
3.673	128.907	1.945	37.127
3.634	128.178	1.927	36.398
3.610	127.825	1.894	35.504
3.591	128.013	1.843	33.411
3.563	127.026	1.781	31.013
3.521	125.380	1.712	28.661
3.464	122.276	1.646	26.615
3.397	119.195	1.595	24.899
3.324	115.244		

TEST 45
RUN 24

TABLE II.- Continued

(b) Continued

y, cm	Pitot pressure, kPa	y, cm	Pitot pressure, kPa	y, cm	Pitot pressure, kPa
1.564	24.698	1.150	14.781	.602	7.539
1.560	24.552	1.143	14.904	.597	7.509
1.558	24.321	1.128	14.842	.594	7.470
1.555	24.360	1.107	14.497	.588	7.447
1.548	24.037	1.087	14.074	.573	7.293
1.534	23.406	1.071	13.682	.551	7.086
1.515	22.768	1.060	13.290	.528	6.786
1.496	22.399	1.027	12.544	.509	6.540
1.480	22.153	1.007	12.121	.493	6.348
1.471	21.984	.985	11.821	.485	6.194
1.465	21.761	.967	11.568	.480	6.156
1.461	21.638	.954	11.475	.477	6.171
1.458	21.600	.944	11.514	.473	6.171
1.452	21.415	.937	11.637	.463	6.094
1.438	21.162	.933	11.575	.445	5.925
1.418	20.708	.929	11.506	.422	5.717
1.398	20.239	.918	11.437	.400	5.533
1.381	20.016	.899	11.183	.383	5.364
1.370	19.701	.876	10.822	.371	5.179
1.363	19.493	.855	10.676	.365	5.087
1.360	19.194	.840	10.645	.361	5.010
1.357	19.063	.830	10.668	.358	5.010
1.353	19.109	.825	10.645	.351	5.018
1.341	18.971	.820	10.430	.337	4.941
1.321	18.609	.816	10.176	.317	4.772
1.300	18.202	.809	9.946	.296	4.541
1.281	17.756	.793	9.715	.278	4.288
1.268	17.272	.772	9.461	.266	4.088
1.259	17.033	.751	9.338	.258	3.957
1.255	16.718	.735	9.246	.254	3.919
1.251	16.618	.723	9.100	.250	3.895
1.249	16.695	.717	9.023	.246	3.865
1.240	16.726	.712	8.938	.234	3.749
1.224	16.472	.709	8.785	.214	3.588
1.201	16.042	.701	8.654	.194	3.473
1.183	15.580	.684	8.439	.179	3.450
1.169	15.173	.663	8.162	.170	3.442
1.161	14.889	.640	7.924	.166	3.465
1.157	14.819	.622	7.770		
1.153	14.766	.609	7.632		

TEST 45
RUN 16

TABLE II.- Continued

(b) Continued

y, cm	Pitot pressure, kPa	y, cm	Pitot pressure, kPa	y, cm	Pitot pressure, kPa
5.360	142.416	3.897	135.490	2.246	47.703
5.351	142.440	3.873	135.095	2.213	46.355
5.347	142.440	3.856	134.979	2.163	43.892
5.343	142.556	3.830	134.770	2.102	41.149
5.342	142.556	3.791	133.817	2.034	37.849
5.340	142.463	3.737	132.166	1.969	35.176
5.334	142.370	3.673	130.214	1.919	33.479
5.314	142.509	3.605	127.704	1.886	32.456
5.279	142.811	3.546	125.333	1.867	31.875
5.230	143.090	3.503	124.125	1.851	31.132
5.175	143.416	3.475	123.474	1.824	30.225
5.128	143.625	3.456	123.055	1.781	28.714
5.095	143.555	3.436	122.498	1.725	26.855
5.074	143.602	3.401	120.406	1.660	24.763
5.056	143.695	3.352	117.012	1.595	22.764
5.036	143.555	3.290	114.688		
4.998	143.346	3.224	111.643		
4.947	143.114	3.160	107.622		
4.886	142.858	3.111	103.718		
4.819	142.509	3.079	101.022		
4.759	142.137	3.058	98.628		
4.714	142.044	3.040	97.558		
4.686	142.161	3.014	96.768		
4.668	142.370	2.971	94.746		
4.646	142.300	2.914	90.609		
4.613	142.207	2.849	84.984		
4.564	142.184	2.782	79.360		
4.504	141.649	2.727	75.455		
4.437	141.092	2.690	73.293		
4.373	140.929	2.668	72.433		
4.322	140.441	2.653	71.527		
4.289	140.046	2.630	70.225		
4.269	139.790	2.592	68.041		
4.251	139.650	2.540	64.484		
4.222	139.534	2.478	60.812		
4.180	139.325	2.410	57.419		
4.122	138.883	2.350	54.281		
4.056	138.558	2.309	51.120		
3.989	137.675	2.283	49.168		
3.934	136.304	2.265	48.610		

TEST 45
RUN 25

TABLE II.- Continued

(b) Continued

y, cm	Pitot pressure, kPa	y, cm	Pitot pressure, kPa	y, cm	Pitot pressure, kPa
1.585	23.005	1.065	11.863	.500	5.767
1.582	22.760	1.060	11.810	.481	5.599
1.571	22.361	1.055	11.840	.467	5.468
1.552	21.816	1.051	11.856	.460	5.361
1.532	21.494	1.041	11.764	.455	5.254
1.514	21.088	1.023	11.457	.452	5.231
1.502	20.528	.998	11.043	.447	5.200
1.476	19.815	.974	10.782	.435	5.131
1.459	19.409	.954	10.568	.415	4.970
1.439	18.864	.941	10.391	.392	4.786
1.418	18.573	.933	10.337	.371	4.617
1.403	18.351	.929	10.307	.356	4.479
1.394	17.998	.926	10.238	.346	4.364
1.388	17.783	.918	10.161	.341	4.295
1.385	17.630	.901	9.954	.338	4.280
1.382	17.561	.877	9.755	.335	4.249
1.375	17.438	.853	9.563	.326	4.203
1.359	17.085	.833	9.348	.309	4.103
1.338	16.618	.819	9.126	.286	3.935
1.316	16.273	.784	8.535	.264	3.735
1.300	15.881	.762	8.390	.250	3.613
1.290	15.713	.738	8.183	.242	3.482
1.283	15.536	.716	7.983	.239	3.429
1.279	15.383	.701	7.761		
1.274	15.260	.690	7.615		
1.269	15.053	.685	7.477		
1.256	14.892	.682	7.447		
1.236	14.593	.679	7.447		
1.214	14.256	.670	7.454		
1.195	14.033	.653	7.347		
1.181	13.757	.630	7.140		
1.173	13.581	.608	6.910		
1.168	13.458	.591	6.687		
1.166	13.474	.579	6.549		
1.162	13.389	.573	6.457		
1.153	13.083	.570	6.381		
1.134	12.761	.566	6.312		
1.111	12.400	.560	6.258		
1.090	12.070	.547	6.135		
1.075	11.948	.524	5.982		

TEST 44
RUN 2

TABLE II.- Continued

(b) Continued

y, cm	Pitot pressure, kPa	y, cm	Pitot pressure, kPa	y, cm	Pitot pressure, kPa
5.638	143.596	4.069	138.056	2.308	54.300
5.639	143.950	4.054	137.750	2.288	52.414
5.619	144.374	4.041	137.797	2.275	52.249
5.578	144.421	4.019	138.103	2.268	52.131
5.522	144.515	3.977	138.056	2.246	50.929
5.456	144.421	3.919	137.255	2.202	49.184
5.386	144.397	3.848	135.652	2.136	46.379
5.336	144.350	3.775	133.672	2.060	42.843
5.304	144.138	3.718	131.904	1.976	38.741
5.288	143.997	3.682	131.196	1.909	35.559
5.279	144.020	3.659	131.196	1.866	33.437
5.276	144.162	3.648	130.937	1.841	32.636
5.259	144.067	3.638	130.631	1.825	32.707
5.226	144.350	3.623	130.466	1.817	32.400
5.174	144.327	3.588	129.593	1.802	31.929
5.114	144.280	3.534	126.930	1.767	30.538
5.048	144.138	3.458	123.724	1.708	28.534
4.996	144.327	3.377	120.164	1.634	26.177
4.963	144.350	3.305	116.133	1.550	23.961
4.945	144.138	3.253	113.422	1.475	22.146
4.935	143.879	3.220	112.526	1.422	20.849
4.930	143.525	3.202	113.422	1.393	19.977
4.920	143.549	3.190	113.563	1.376	19.505
4.894	143.431	3.176	112.220	1.368	19.435
4.846	143.337	3.145	109.226	1.350	19.034
4.783	143.195	3.097	105.690	1.312	18.115
4.708	142.959	3.026	101.258		
4.636	142.559	2.944	95.978		
4.579	142.205	2.865	89.778		
4.542	142.323	2.805	84.733		
4.518	142.182	2.767	81.103		
4.507	141.899	2.746	79.547		
4.492	141.545	2.733	78.722		
4.469	141.215	2.720	77.944		
4.422	140.885	2.690	76.035		
4.362	140.414	2.640	72.876		
4.284	139.966	2.569	70.023		
4.206	139.117	2.489	65.497		
4.141	138.551	2.409	60.665		
4.096	138.528	2.347	57.081		

TEST 44
RUN 33

TABLE II.- Continued

(b) Continued

y, cm	Pitot pressure, kPa	y, cm	Pitot pressure, kPa	y, cm	Pitot pressure, kPa
1.302	18.003	.776	9.435	.265	4.190
1.289	17.718	.771	9.350	.262	4.228
1.267	17.195	.755	9.196	.256	4.182
1.243	16.534	.731	8.920	.239	4.020
1.222	15.903	.706	8.650	.215	3.713
1.206	15.411	.685	8.304	.188	3.282
1.197	15.126	.670	8.027	.164	2.882
1.191	15.103	.661	7.943		
1.188	15.265	.657	8.020		
1.185	15.326	.653	8.066		
1.182	15.303	.651	8.066		
1.168	14.995	.647	8.012		
1.146	14.588	.635	7.866		
1.121	14.196	.613	7.635		
1.097	13.880	.587	7.312		
1.080	13.657	.564	7.028		
1.069	13.380	.547	6.935		
1.063	13.280	.537	6.897		
1.059	13.296	.530	6.889		
1.057	13.226	.527	6.843		
1.053	13.173	.524	6.835		
1.039	13.019	.521	6.805		
1.015	12.727	.512	6.689		
.988	12.257	.494	6.481		
.961	11.904	.469	6.235		
.941	11.611	.444	5.935		
.927	11.342	.424	5.751		
.919	11.227	.411	5.651		
.915	11.219	.403	5.635		
.912	11.204	.399	5.635		
.909	11.111	.397	5.651		
.901	11.019	.394	5.620		
.882	10.788	.386	5.543		
.857	10.481	.368	5.343		
.831	10.081	.343	5.112		
.810	9.812	.317	4.851		
.796	9.612	.295	4.636		
.787	9.573	.280	4.413		
.782	9.612	.271	4.274		
.779	9.535	.267	4.174		

TEST 44
RUN 7

TABLE II.- Continued

(b) Continued

y, cm	Pitot pressure, kPa	y, cm	Pitot pressure, kPa	y, cm	Pitot pressure, kPa
5.402	142.767	3.929	139.038	2.377	65.543
5.357	143.101	3.855	137.270	2.304	61.671
5.333	143.269	3.796	136.027	2.230	56.867
5.321	142.982	3.756	135.429	2.167	52.637
5.316	142.862	3.731	135.190	2.127	49.936
5.312	143.054	3.715	135.238	2.104	48.526
5.297	142.982	3.704	135.644	2.093	47.617
5.261	142.599	3.684	135.262	2.085	47.307
5.213	143.006	3.647	133.995	2.069	46.375
5.152	143.651	3.587	132.418	2.034	45.132
5.092	144.320	3.517	130.506	1.979	42.670
5.042	144.774	3.437	127.829	1.909	38.941
5.012	145.157	3.368	125.391	1.838	35.452
4.991	145.181	3.321	123.407	1.779	33.062
4.979	145.396	3.294	122.332	1.744	31.891
4.973	145.515	3.276	121.543	1.724	31.102
4.963	145.683	3.265	121.447	1.713	30.696
4.932	145.444	3.251	121.614	1.708	30.720
4.886	145.061	3.221	120.491	1.697	30.313
4.822	144.416	3.171	117.527	1.672	29.262
4.745	143.747	3.105	114.229	1.623	27.636
4.674	143.436	3.031	110.238	1.556	25.509
4.622	143.006	2.965	105.792	1.478	22.952
4.587	142.504	2.917	102.542	1.404	20.753
4.566	142.599	2.887	100.295	1.348	19.367
4.552	143.101	2.870	98.980	1.312	18.578
4.535	143.388	2.863	97.738	1.293	18.267
4.507	143.269	2.856	97.260	1.283	18.076
4.466	143.077	2.833	96.829	1.272	17.885
4.404	142.767	2.794	94.965	1.248	17.431
4.331	142.384	2.737	91.093	1.205	16.499
4.261	141.835	2.664	86.026	1.143	15.232
4.205	141.548	2.599	80.505		
4.168	141.476	2.552	76.442		
4.150	141.357	2.523	73.956		
4.138	141.524	2.508	73.383		
4.127	141.715	2.499	73.144		
4.103	141.691	2.491	72.283		
4.061	140.783	2.472	70.658		
4.001	140.066	2.434	68.411		

(b) Continued

y, cm	Pitot pressure, kPa	y, cm	Pitot pressure, kPa
1.093	14.158	.613	7.832
1.084	13.854	.607	7.770
1.066	13.590	.592	7.715
1.043	13.317	.569	7.474
1.022	13.052	.544	7.170
1.007	12.826	.522	6.936
.996	12.608	.506	6.796
.990	12.421	.496	6.757
.987	12.468	.490	6.640
.985	12.522	.486	6.601
.984	12.343	.483	6.656
.975	12.125	.481	6.648
.958	11.837	.473	6.508
.934	11.587	.455	6.297
.911	11.307	.431	6.056
.894	11.065	.409	5.853
.882	10.902	.394	5.705
.874	10.793	.383	5.596
.870	10.777	.377	5.511
.867	10.910	.374	5.440
.864	10.964	.371	5.409
.857	10.746	.368	5.464
.841	10.497	.361	5.456
.818	10.263	.347	5.324
.794	10.006	.325	5.152
.774	9.764	.302	4.926
.761	9.554	.283	4.669
.752	9.383	.269	4.482
.747	9.219	.260	4.428
.744	9.110	.255	4.420
.741	8.977	.252	4.389
.736	8.977	.250	4.396
.721	8.985	.247	4.365
.698	8.837	.236	4.264
.673	8.494	.215	4.054
.650	8.191	.192	3.726
.634	7.965	.172	3.430
.624	7.856	.157	3.197
.618	7.840		
.615	7.856		

TEST 44
RUN 9

TABLE II.- Continued

(b) Continued

y, cm	Pitot pressure, kPa	y, cm	Pitot pressure, kPa	y, cm	Pitot pressure, kPa
5.353	142.202	3.523	128.541	1.723	28.674
5.343	142.297	3.501	128.327	1.693	27.410
5.322	142.369	3.487	128.374	1.677	26.838
5.285	142.321	3.465	127.850	1.667	26.647
5.232	142.607	3.422	125.990	1.645	26.170
5.167	142.631	3.362	123.177	1.606	24.859
5.092	142.512	3.288	120.746	1.547	23.238
5.021	142.536	3.205	116.407	1.472	21.402
4.965	142.464	3.130	112.091	1.388	19.281
4.929	142.703	3.073	108.515		
4.906	142.440	3.037	104.963		
4.892	142.321	3.017	103.151		
4.875	142.464	3.004	102.794		
4.846	142.512	2.990	102.436		
4.797	142.536	2.962	101.149		
4.731	142.464	2.914	98.812		
4.656	142.417	2.845	95.284		
4.578	141.630	2.769	90.182		
4.517	140.605	2.695	83.531		
4.473	139.770	2.644	77.976		
4.448	139.103	2.614	75.353		
4.434	138.364	2.598	74.447		
4.421	138.674	2.587	74.400		
4.396	139.580	2.578	74.161		
4.353	140.366	2.555	72.540		
4.292	139.603	2.514	70.108		
4.218	138.840	2.451	66.318		
4.140	138.578	2.375	61.454		
4.071	138.340	2.296	55.876		
4.023	138.125	2.225	50.893		
3.993	138.078	2.176	47.913		
3.977	138.221	2.147	46.101		
3.961	137.863	2.133	45.600		
3.938	136.290	2.120	45.696		
3.902	134.597	2.100	44.933		
3.845	134.025	2.061	43.192		
3.772	133.762	2.002	40.618		
3.691	133.190	1.928	37.685		
3.615	131.879	1.850	34.062		
3.559	129.638	1.776	30.867		

TEST 44
RUN 35

TABLE II.- Continued

(b) Continued

y, cm	Pitot pressure, kPa	y, cm	Pitot pressure, kPa	y, cm	Pitot pressure, kPa
1.359	17.997	.854	9.752	.319	4.506
1.354	17.777	.852	9.699	.317	4.415
1.337	17.685	.846	9.630	.315	4.385
1.314	17.289	.830	9.470	.309	4.362
1.289	16.772	.806	9.173	.293	4.278
1.267	16.376	.779	8.869	.270	4.027
1.252	16.033	.757	8.625	.244	3.753
1.242	15.744	.741	8.397	.224	3.502
1.238	15.576	.733	8.268	.208	3.311
1.236	15.614	.727	8.207	.198	3.159
1.234	15.683	.724	8.138	.193	3.096
1.228	15.599	.722	8.161	.191	3.083
1.212	15.219	.718	8.161	.190	3.058
1.187	14.587	.706	8.085	.187	3.007
1.161	14.054	.684	7.872	.175	2.892
1.139	13.757	.657	7.590		
1.124	13.719	.633	7.346		
1.115	13.620	.615	7.156		
1.110	13.323	.606	6.958		
1.108	12.980	.600	6.889		
1.107	12.836	.597	6.905		
1.103	12.866	.596	6.935		
1.091	12.607	.591	6.928		
1.068	12.341	.578	6.867		
1.040	12.158	.556	6.646		
1.016	11.998	.527	6.349		
.999	11.831	.501	6.098		
.988	11.617	.481	5.930		
.983	11.419	.468	5.793		
.979	11.244	.462	5.763		
.978	11.244	.459	5.755		
.976	11.221	.456	5.725		
.967	11.062	.453	5.664		
.948	10.826	.443	5.618		
.922	10.635	.424	5.451		
.897	10.300	.398	5.207		
.880	9.965	.369	4.971		
.869	9.790	.347	4.773		
.862	9.729	.331	4.644		
.858	9.722	.322	4.567		

TEST 44
RUN 14

TABLE II.- Continued

(b) Continued

y, cm	Pitot pressure, kPa	y, cm	Pitot pressure, kPa	y, cm	Pitot pressure, kPa
5.484	144.256	3.900	136.719	2.155	48.770
5.448	144.326	3.864	136.696	2.136	48.112
5.395	144.326	3.812	136.132	2.100	46.211
5.331	143.856	3.744	134.113	2.043	43.064
5.273	143.387	3.669	132.470	1.976	39.707
5.230	143.434	3.597	130.568	1.899	35.904
5.200	143.880	3.546	129.488	1.829	32.546
5.183	144.303	3.511	129.582	1.777	30.269
5.171	144.303	3.492	129.323	1.746	29.283
5.158	143.622	3.479	128.596	1.730	28.719
5.133	143.739	3.465	128.196	1.720	28.484
5.088	143.575	3.437	127.891	1.707	28.156
5.029	142.025	3.391	126.459	1.682	27.404
4.958	141.133	3.327	123.149	1.637	25.949
4.885	141.415	3.254	119.040	1.577	24.071
4.828	142.495	3.180	114.579	1.502	21.958
4.787	143.246	3.121	110.611	1.429	19.938
4.761	143.082	3.079	109.156	1.372	18.459
4.746	142.354	3.055	108.944		
4.735	141.485	3.042	109.038		
4.719	141.391	3.030	108.217		
4.687	141.790	3.006	106.761		
4.635	141.837	2.965	103.685		
4.569	141.462	2.907	99.201		
4.499	141.368	2.837	94.223		
4.436	141.180	2.761	88.166		
4.391	140.616	2.697	82.813		
4.360	140.523	2.649	79.221		
4.342	140.382	2.622	77.671		
4.329	140.076	2.605	77.178		
4.312	140.123	2.591	76.638		
4.280	139.865	2.566	74.384		
4.230	139.630	2.523	70.135		
4.164	139.443	2.461	65.439		
4.092	138.762	2.392	60.978		
4.026	137.517	2.314	56.447		
3.980	136.437	2.249	52.197		
3.949	135.991	2.205	49.192		
3.931	136.320	2.180	48.347		
3.919	136.649	2.165	48.394		

TEST 44
RUN 31

TABLE II.- Continued

(b) Continued

y, cm	Pitot pressure, kPa	y, cm	Pitot pressure, kPa	y, cm	Pitot pressure, kPa
1.333	17.790	.847	9.755	.292	4.165
1.322	17.643	.829	9.640	.285	4.142
1.304	17.165	.804	9.408	.263	4.027
1.289	16.780	.776	9.162	.243	3.803
1.279	16.610	.755	8.930	.217	3.541
1.274	16.718	.740	8.699	.194	3.279
1.271	16.841	.731	8.529	.180	3.101
1.271	16.803	.727	8.475	.171	2.963
1.270	16.795	.724	8.422	.167	2.885
1.267	16.402	.722	8.329	.164	2.816
1.254	16.278	.717	8.221		
1.232	16.047	.702	8.090		
1.206	15.600	.678	7.859		
1.182	15.145	.649	7.589		
1.167	14.752	.625	7.427		
1.155	14.459	.608	7.288		
1.151	14.420	.597	7.180		
1.148	14.266	.591	7.041		
1.146	14.212	.588	6.949		
1.139	14.243	.586	6.918		
1.123	13.981	.581	6.926		
1.097	13.665	.568	6.864		
1.067	13.171	.546	6.710		
1.039	12.577	.519	6.455		
1.019	12.130	.494	6.209		
1.005	11.907	.474	5.993		
.998	11.806	.460	5.854		
.993	11.745	.453	5.761		
.991	11.698	.449	5.684		
.987	11.629	.447	5.600		
.978	11.590	.442	5.530		
.956	11.398	.430	5.445		
.929	11.051	.406	5.322		
.904	10.665	.377	5.129		
.884	10.372	.348	4.875		
.870	10.172	.325	4.690		
.863	10.048	.309	4.512		
.859	9.910	.301	4.366		
.857	9.802	.296	4.273		
.855	9.755	.294	4.196		

TEST 44
RUN 4

TABLE II.- Continued

(b) Continued

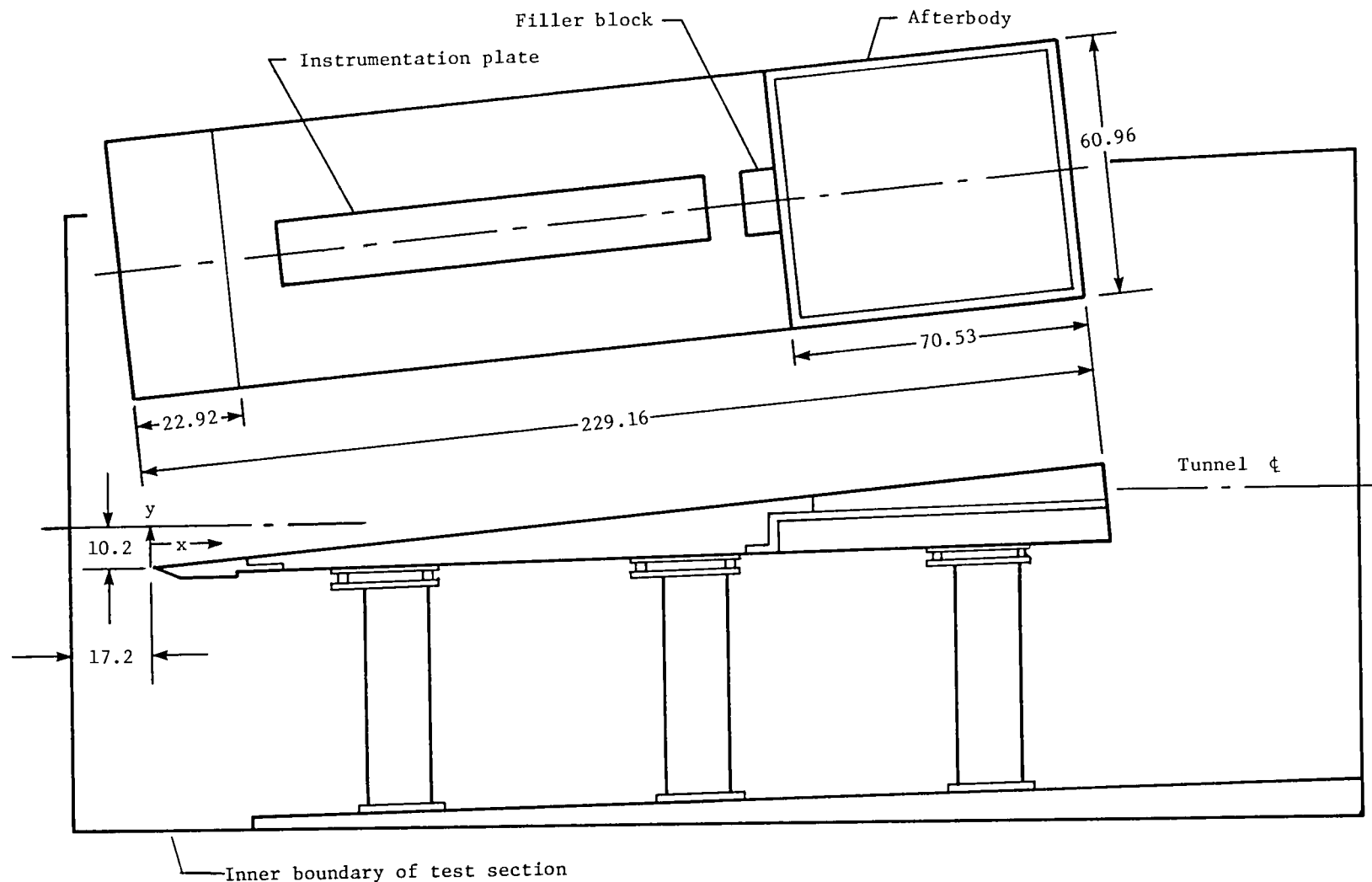
y, cm	Pitot pressure, kPa	y, cm	Pitot pressure, kPa	y, cm	Pitot pressure, kPa
5.467	144.382	3.691	133.326	1.791	31.182
5.397	144.571	3.609	131.299	1.715	28.354
5.348	144.641	3.529	128.564	1.630	25.242
5.317	144.500	3.465	126.230	1.553	22.578
5.299	144.382	3.425	124.981	1.499	20.881
5.285	144.076	3.401	124.887	1.464	19.985
5.264	143.934	3.385	125.005	1.447	19.867
5.226	144.028	3.364	124.604	1.436	19.844
5.176	144.335	3.327	122.364	1.421	19.679
5.109	144.712	3.268	118.216	1.386	18.948
5.037	144.641	3.197	113.807	1.332	17.651
4.972	144.830	3.114	107.961		
4.925	144.924	3.035	103.294		
4.896	144.618	2.976	99.899		
4.877	144.453	2.937	97.895		
4.864	144.288	2.915	96.552		
4.851	144.005	2.904	96.387		
4.820	143.416	2.889	97.212		
4.776	142.968	2.860	95.373		
4.711	142.590	2.809	90.847		
4.636	142.284	2.742	85.331		
4.556	142.001	2.661	78.494		
4.489	141.813	2.579	71.682		
4.443	141.435	2.510	67.132		
4.412	141.577	2.465	65.175		
4.393	141.695	2.437	63.879		
4.379	141.671	2.421	62.653		
4.353	141.530	2.408	61.569		
4.309	141.247	2.383	59.942		
4.246	140.775	2.339	57.467		
4.171	139.432	2.276	53.648		
4.087	138.442	2.198	49.452		
4.013	137.829	2.116	45.374		
3.957	137.145	2.042	41.838		
3.924	135.990	1.989	38.985		
3.901	135.990	1.956	37.547		
3.886	136.320	1.939	37.170		
3.863	136.296	1.925	36.793		
3.824	136.108	1.900	35.732		
3.765	134.929	1.854	33.752		

TEST 44
RUN 36

TABLE II.- Concluded

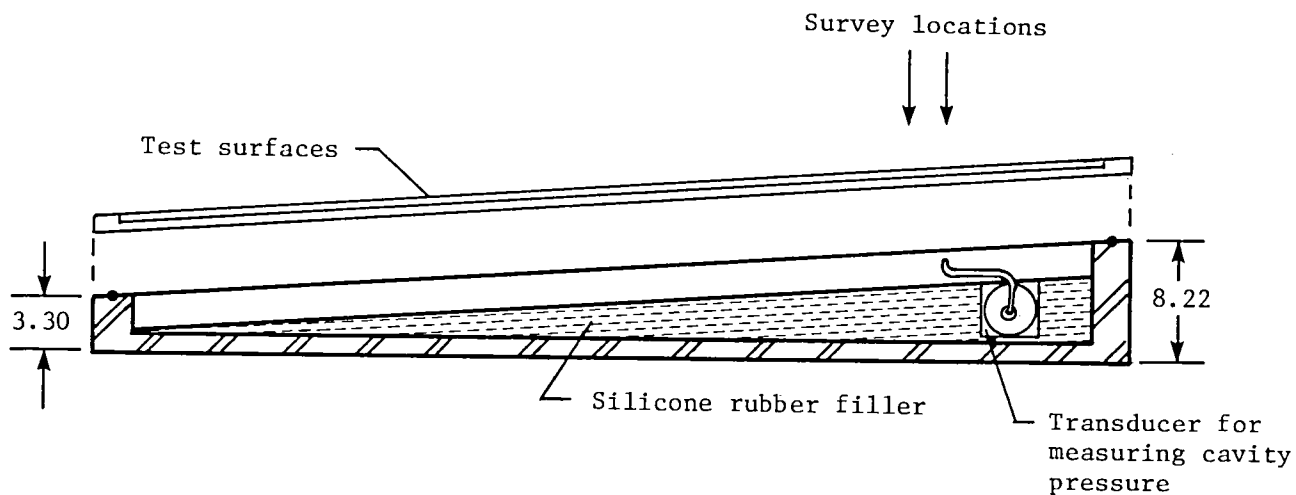
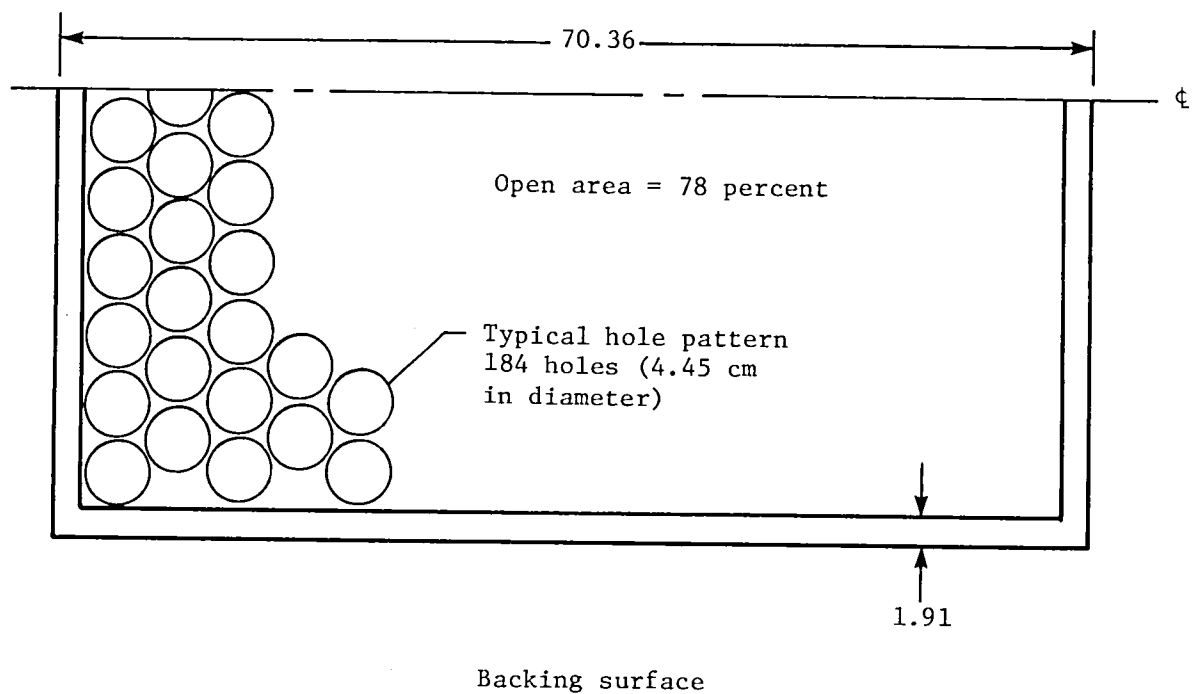
(b) Concluded

y, cm	Pitot pressure, kPa	y, cm	Pitot pressure, kPa	y, cm	Pitot pressure, kPa
1.329	17.150	.781	8.666	.252	3.834
1.326	17.036	.779	8.651	.249	3.781
1.315	16.937	.773	8.651		
1.295	16.762	.759	8.597		
1.271	16.473	.735	8.430		
1.248	16.176	.708	8.141		
1.232	15.849	.685	7.867		
1.222	15.445	.669	7.669		
1.216	15.118	.659	7.547		
1.213	14.974	.654	7.448		
1.210	14.920	.651	7.372		
1.208	14.882	.648	7.357		
1.197	14.799	.644	7.357		
1.175	14.502	.634	7.296		
1.148	14.068	.613	7.098		
1.121	13.596	.588	6.855		
1.099	13.224	.563	6.657		
1.087	12.934	.545	6.459		
1.080	12.828	.532	6.307		
1.075	12.721	.525	6.178		
1.073	12.546	.520	6.117		
1.069	12.417	.518	6.026		
1.057	12.204	.514	5.988		
1.035	11.839	.505	5.949		
1.007	11.550	.487	5.873		
.979	11.359	.461	5.714		
.957	11.108	.435	5.523		
.942	10.857	.414	5.341		
.933	10.621	.400	5.189		
.928	10.484	.392	5.082		
.925	10.416	.388	5.014		
.923	10.325	.385	4.983		
.915	10.256	.383	4.937		
.897	10.051	.375	4.899		
.870	9.853	.359	4.869		
.841	9.587	.335	4.702		
.817	9.275	.308	4.489		
.800	9.077	.285	4.276		
.790	8.902	.268	4.093		
.784	8.742	.257	3.933		



(a) Overall model dimensions.

Figure 1.- Model sketch. All dimensions are given in centimeters.



(b) Afterbody details.

Figure 1.- Concluded.

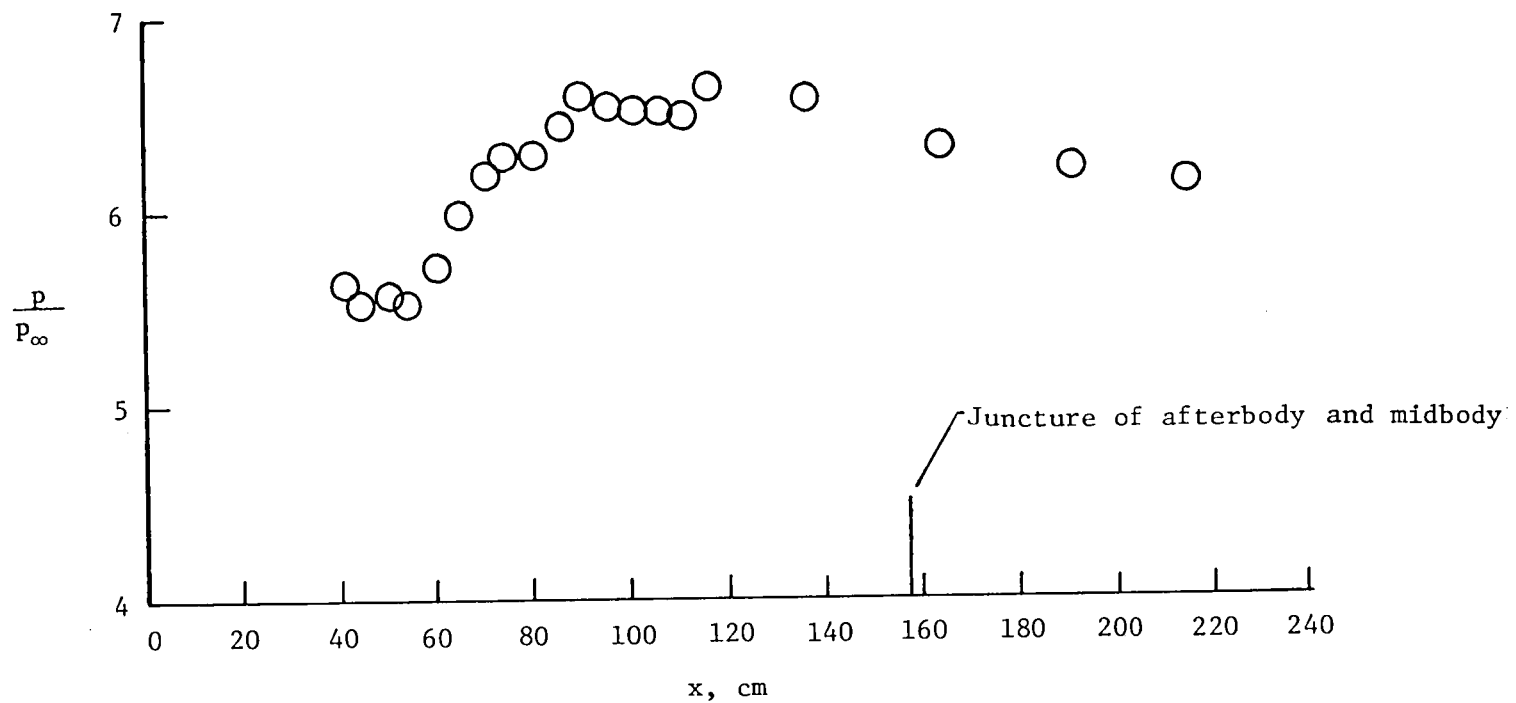


Figure 2.- Pressure distribution on solid surfaces. Data of reference 6.

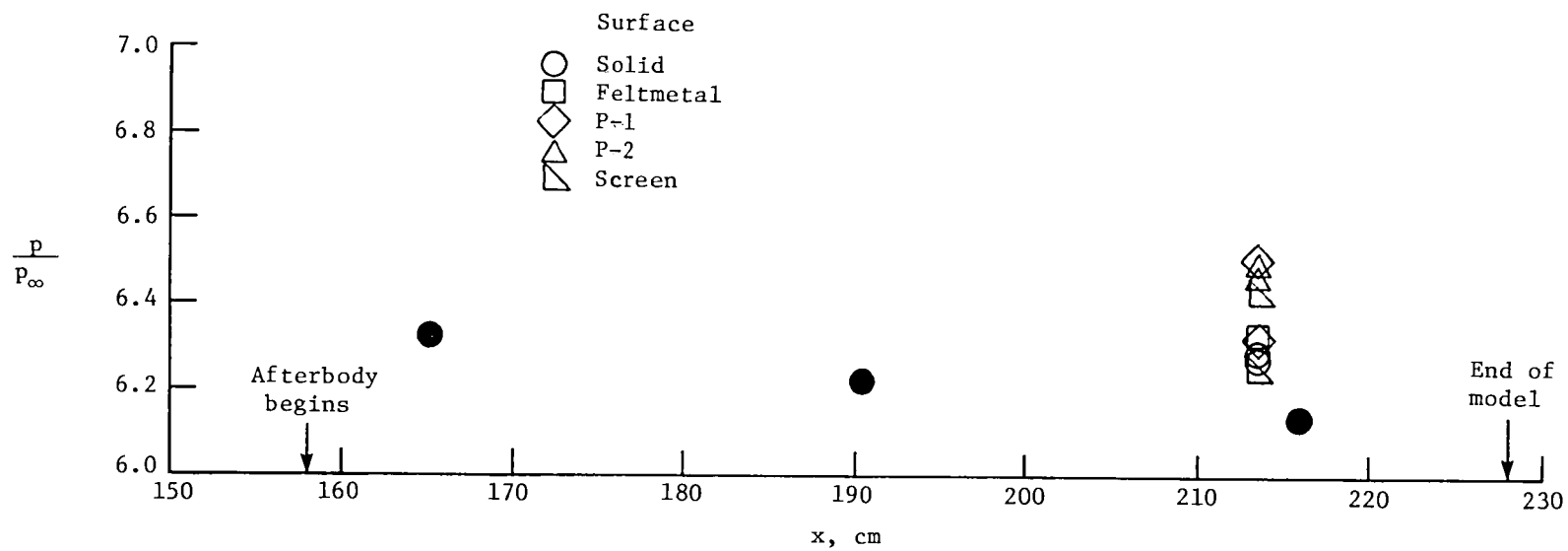
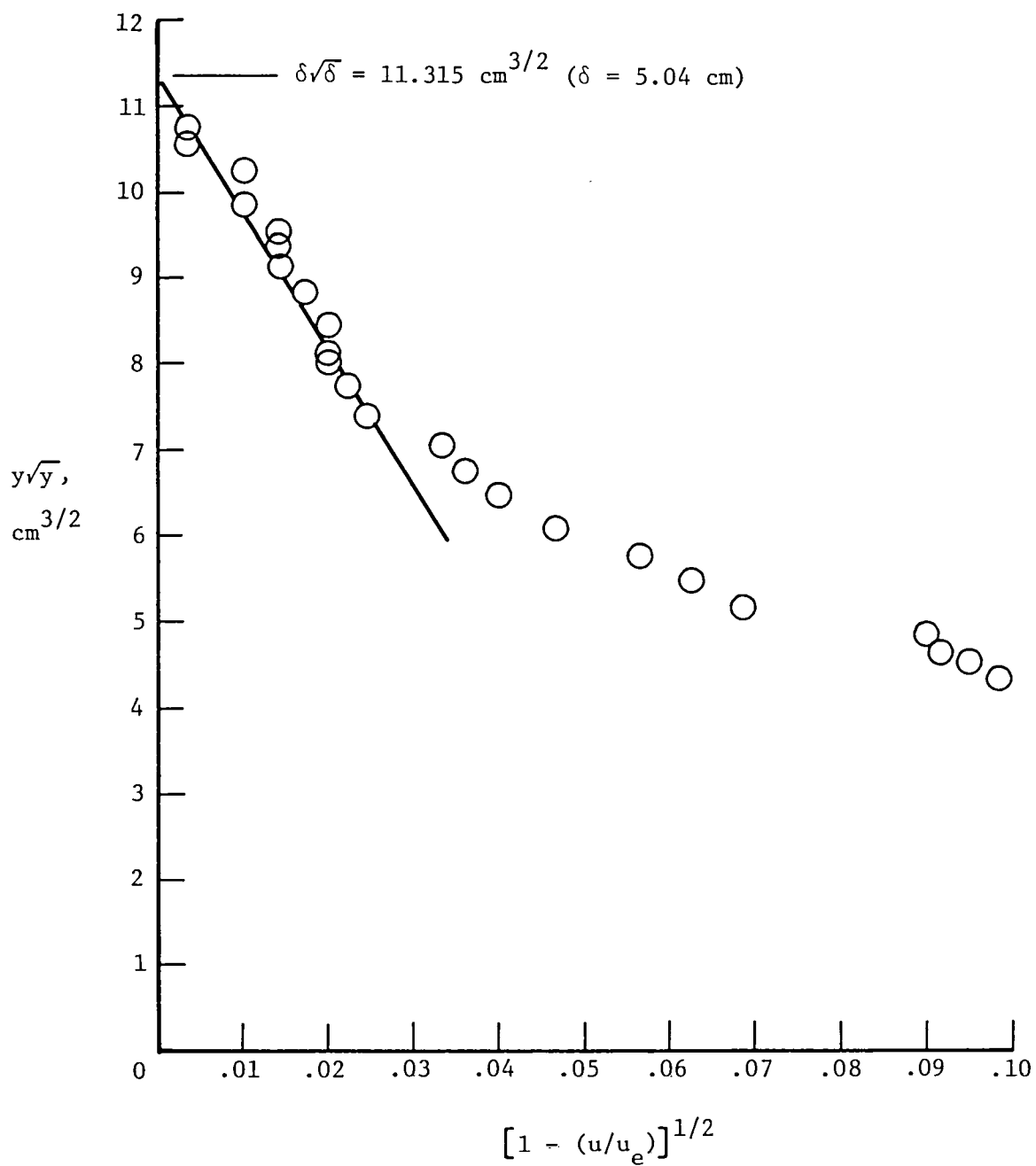
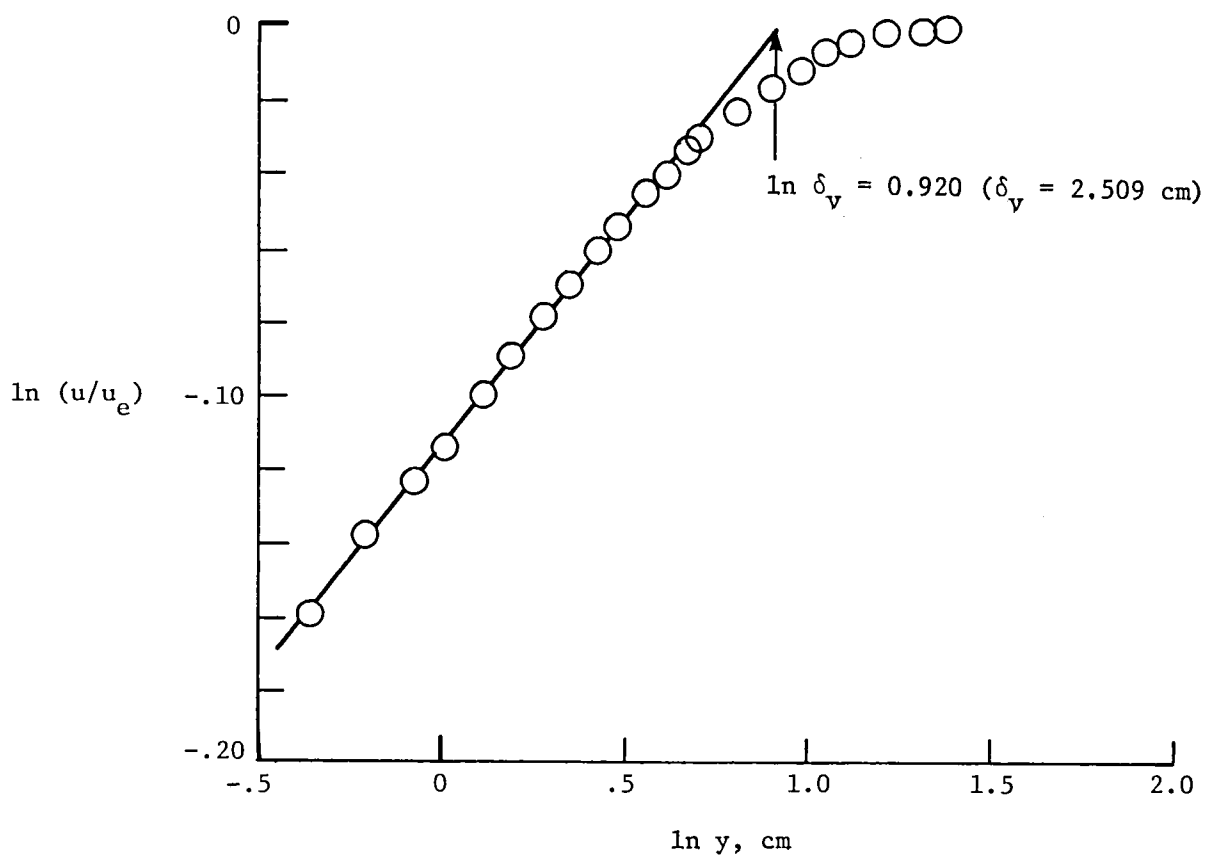


Figure 3.- Cavity pressures measured at $x = 213.4$ cm. Solid symbols denote data of reference 6.



(a) Method of finding δ for runs 19 to 24 on surface P-1
at $x = 213.4 \text{ cm}$.

Figure 4.- Boundary-layer thicknesses.



(b) Method of finding δ_v for runs 17 to 23 on Feltmetal surface
at $x = 213.4 \text{ cm}$.

Figure 4.- Concluded.

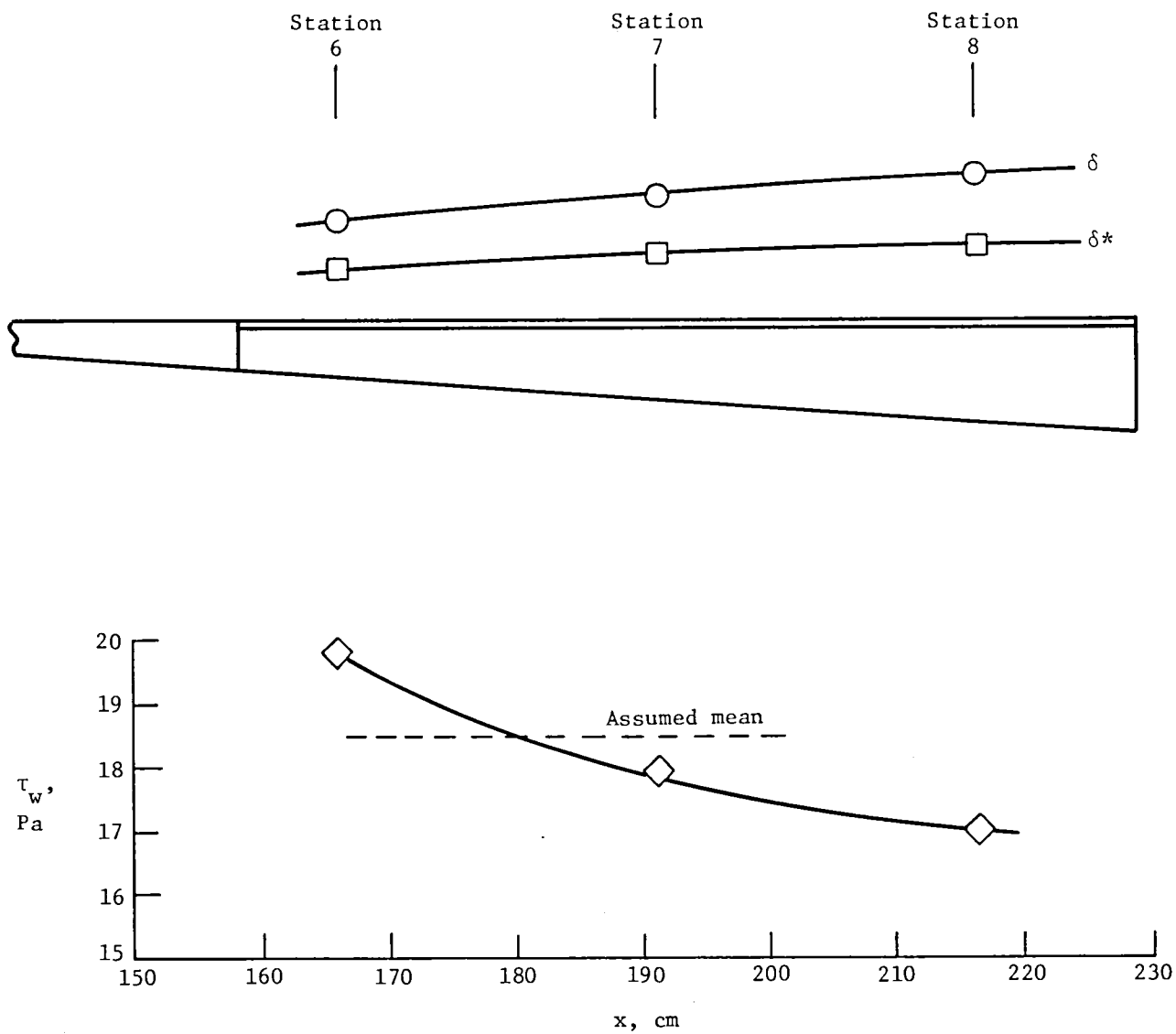


Figure 5.- Turbulent boundary-layer properties (ref. 6).

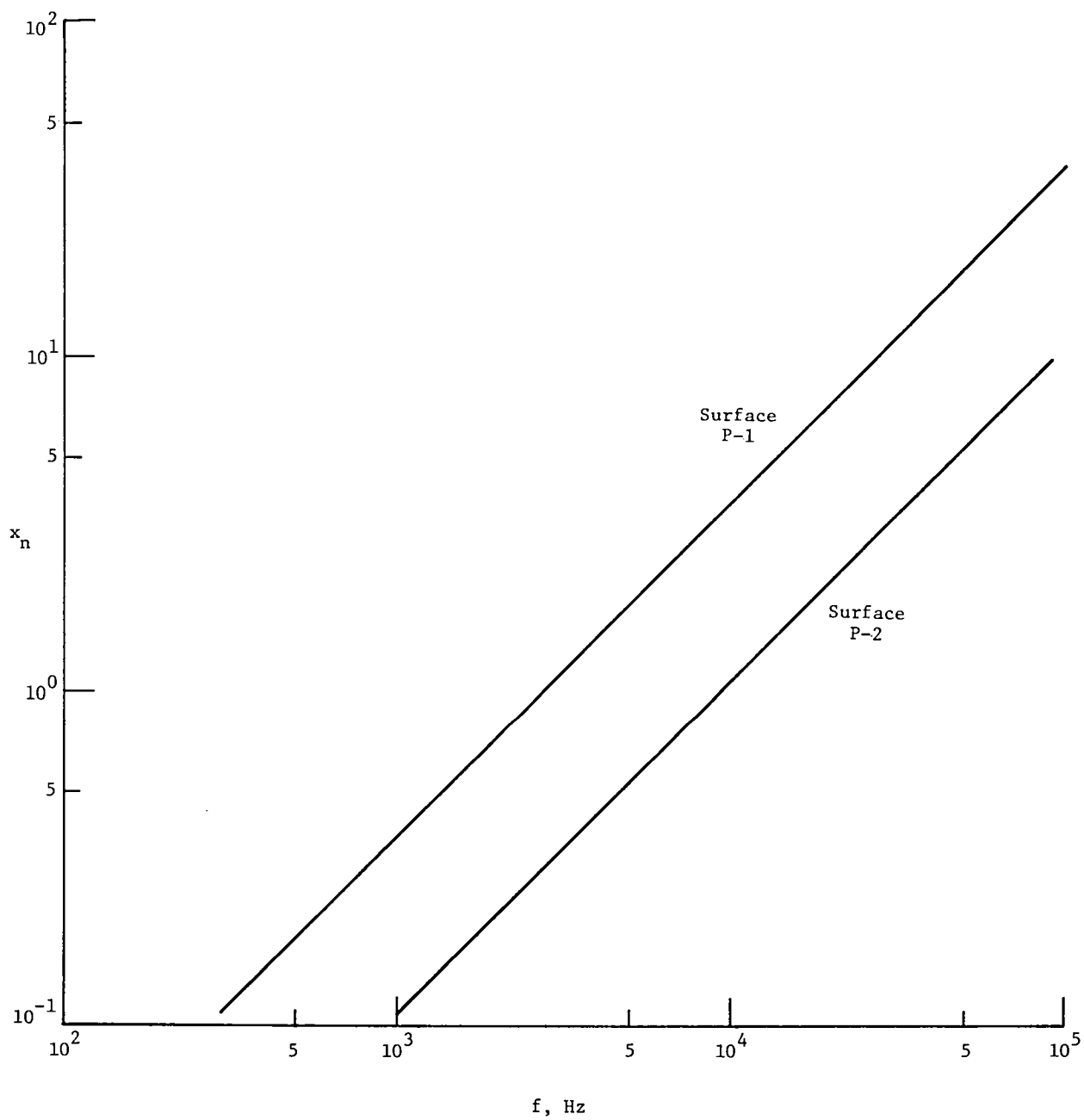


Figure 6.- Calculated reactive component of impedance for perforated steel sheet.

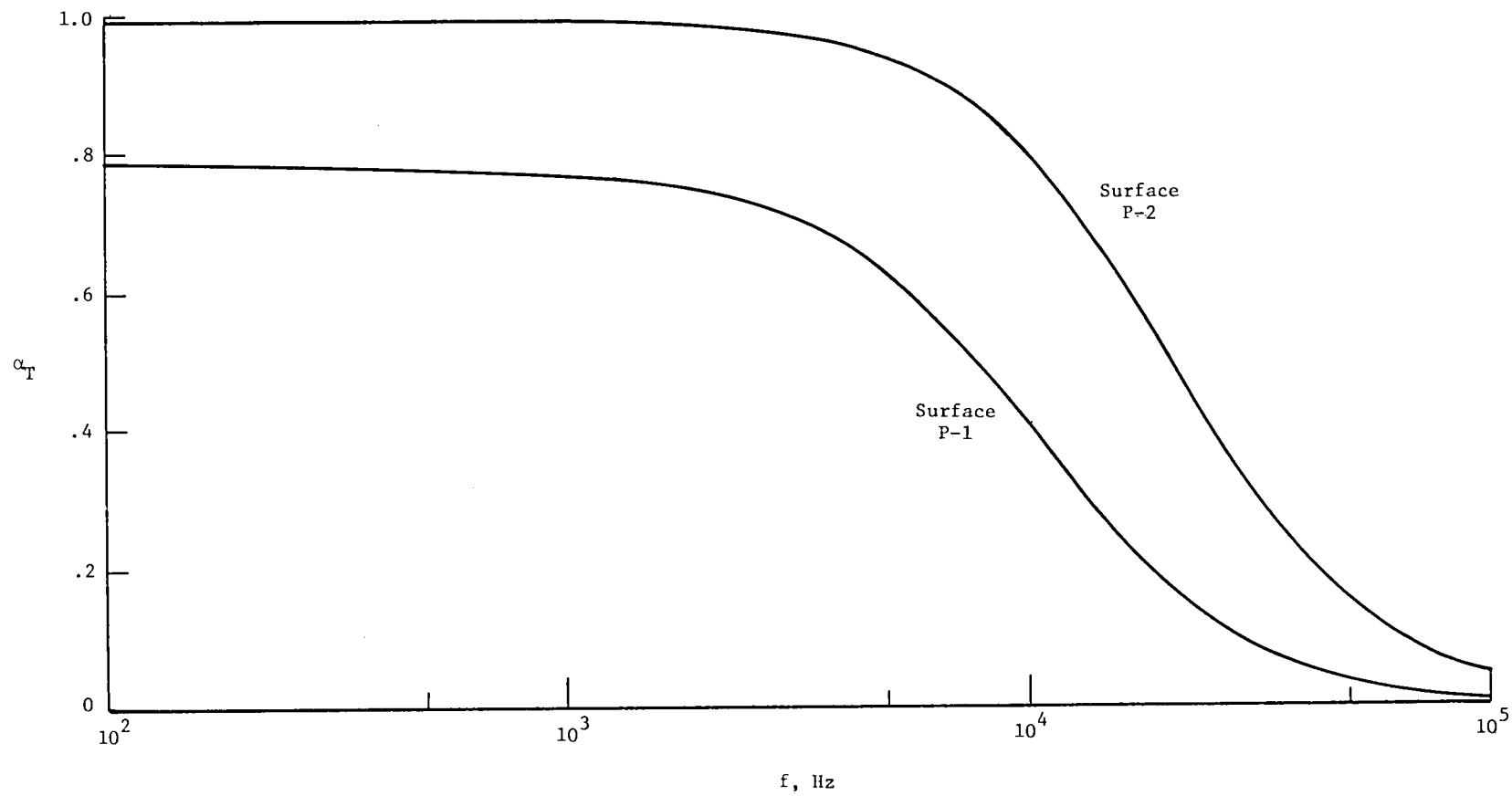
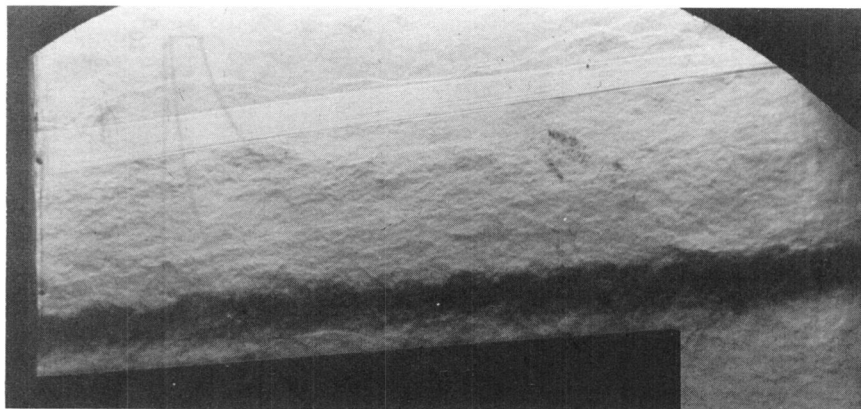
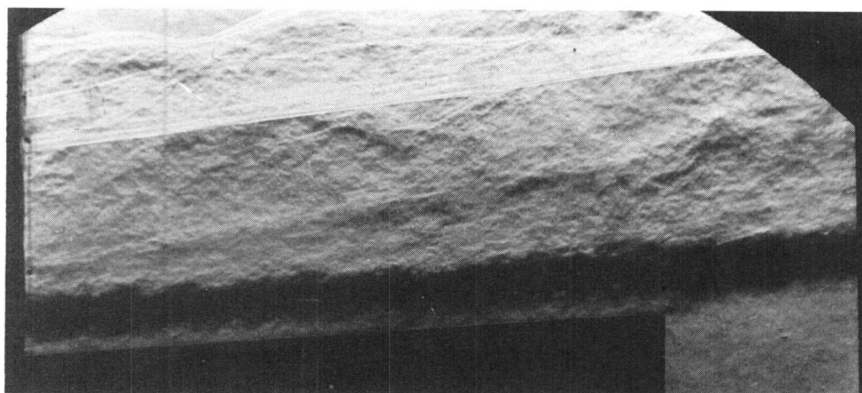


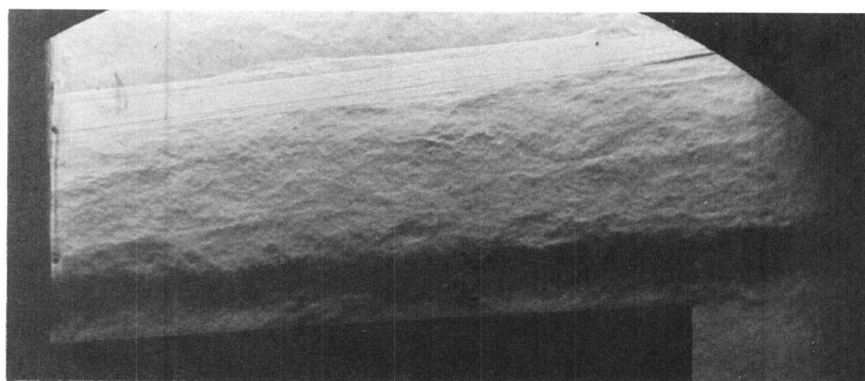
Figure 7.- Sound-power-transmission coefficient for perforated steel sheet for normal plane waves.



(a) Solid surface for $R_{\infty}/m = 42.8 \times 10^6$.



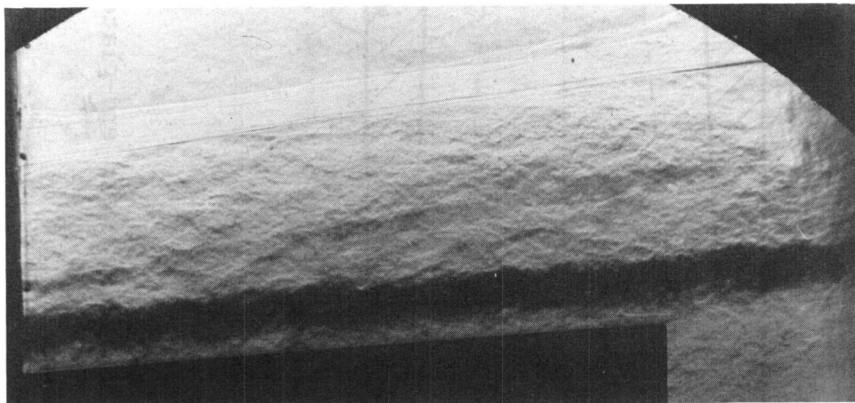
(b) Screen surface with no backing for $R_{\infty}/m = 42.5 \times 10^6$.



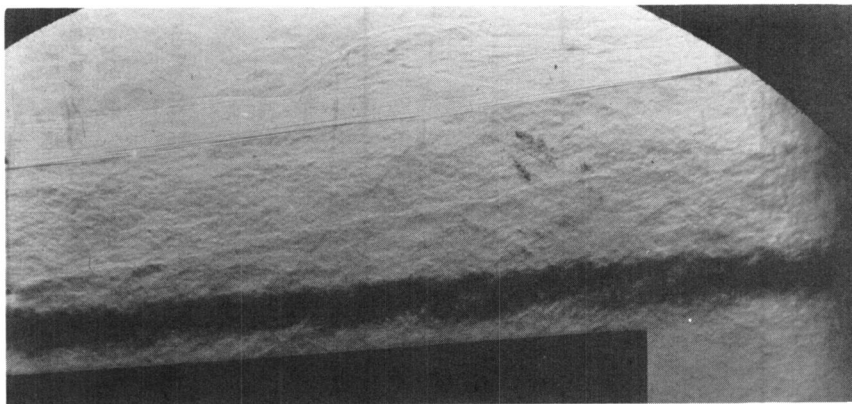
(c) Screen surface with 80 ppi foam backing for $R_{\infty}/m = 42.8 \times 10^6$.

Figure 8.- Schlieren photographs.

L-78-153



(d) P-2 surface with no backing for $R_{\infty}/m = 42.6 \times 10^6$.



(e) Feltmetal surface with 80 ppi foam backing for $R_{\infty}/m = 42.9 \times 10^6$.

Figure 8.- Concluded.

L-78-154

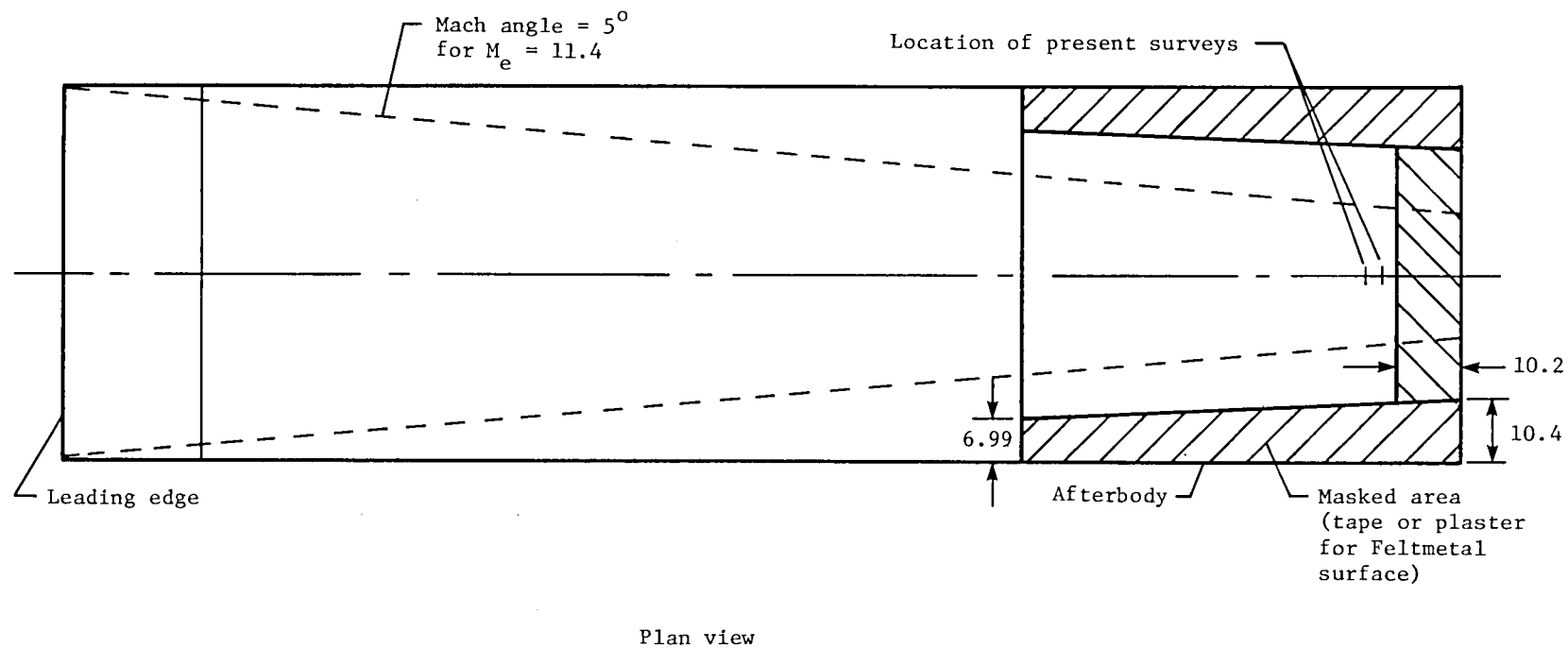
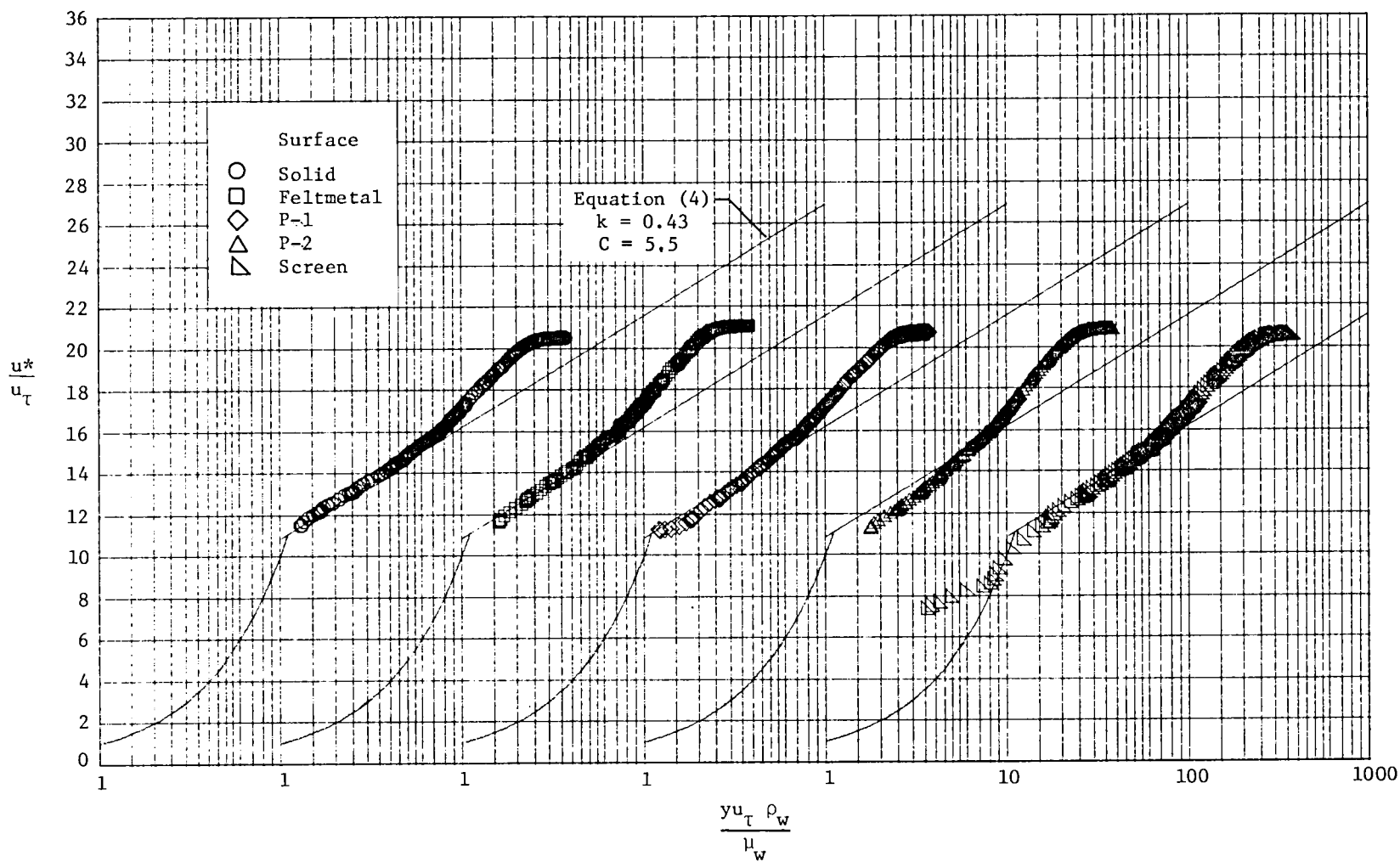
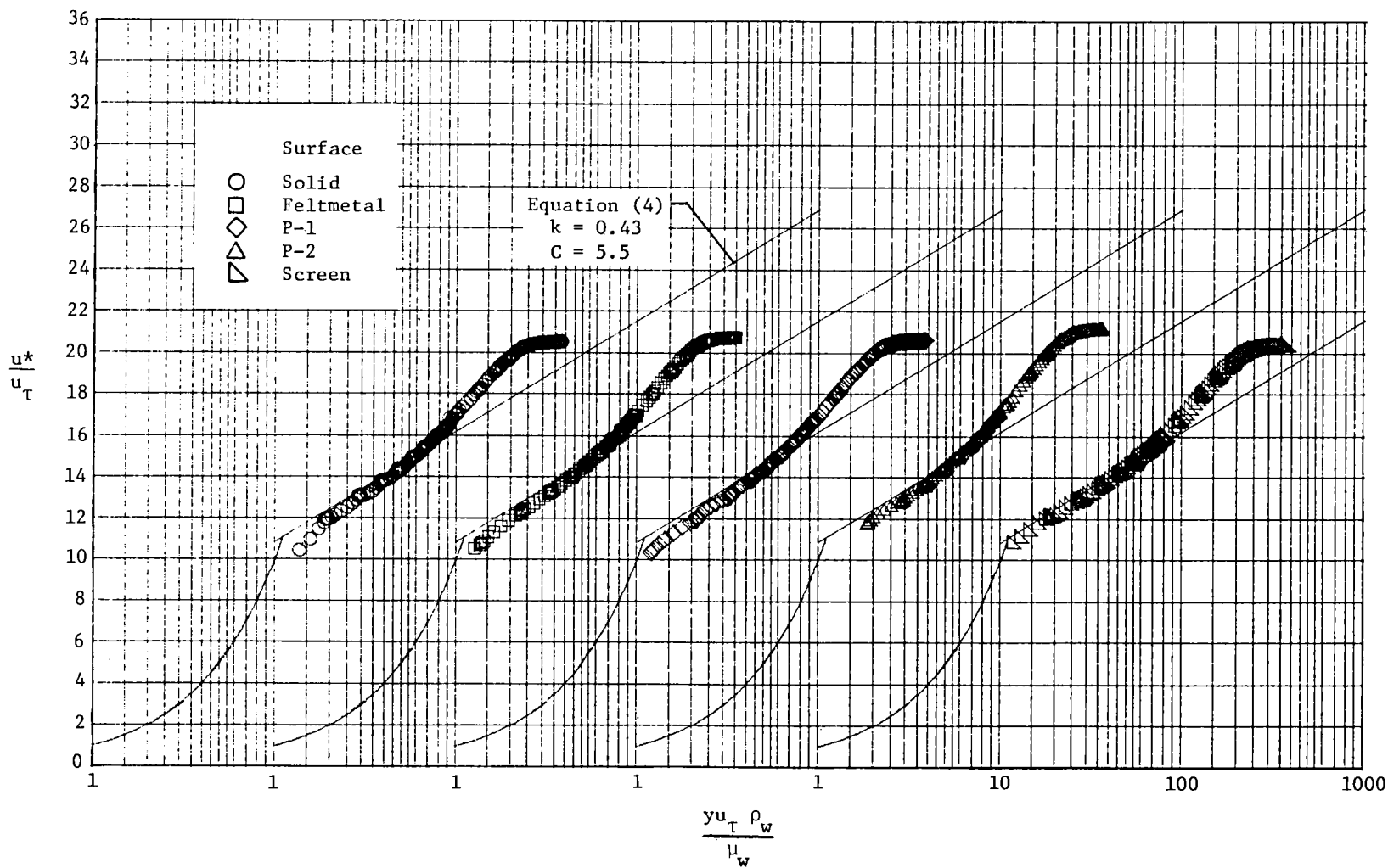


Figure 9.- Masking of afterbody surface to prevent probe interference and end-plate disturbance.
Dimensions of masked area in centimeters.



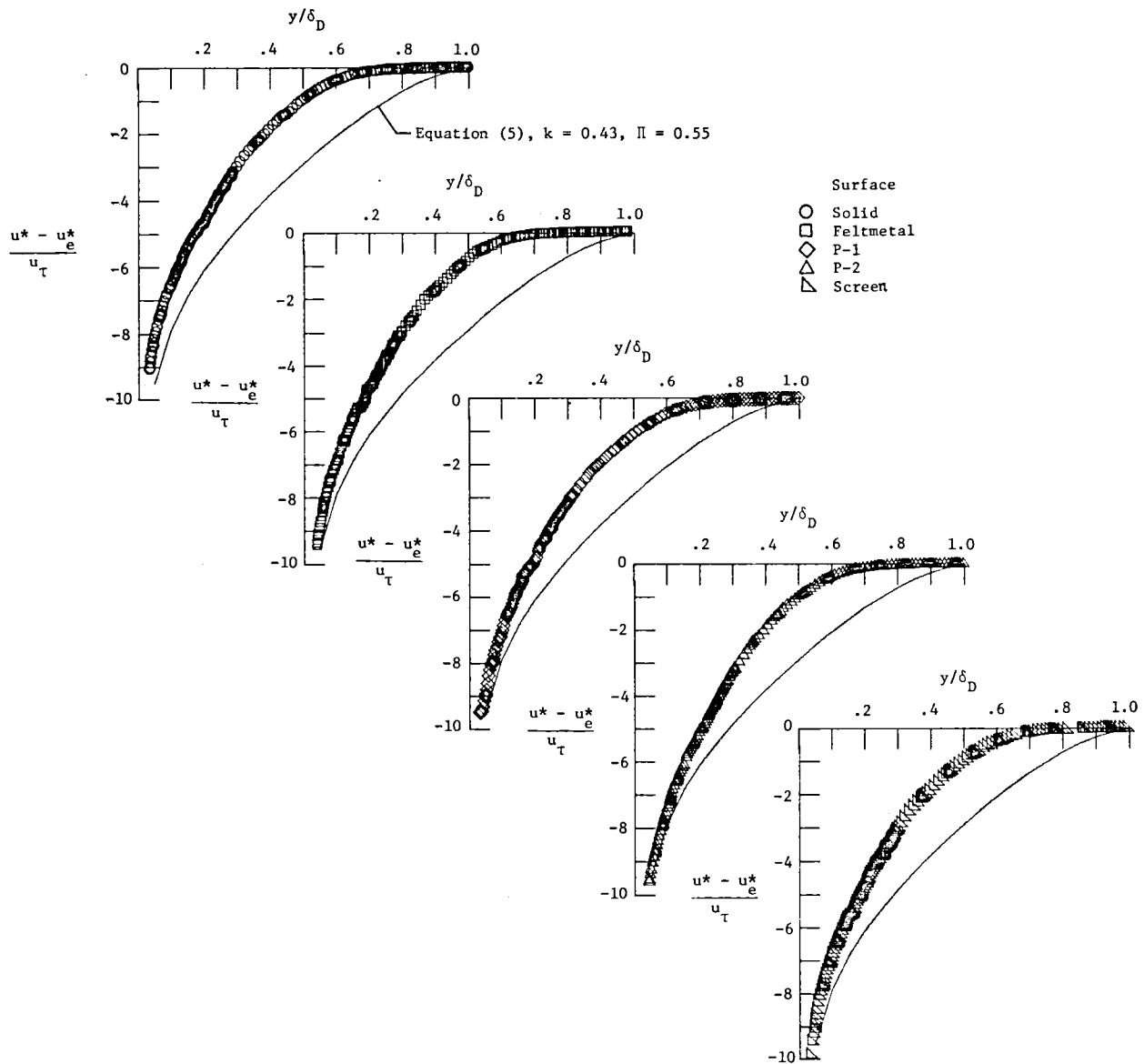
(a) Data at $x = 213.4$ cm.

Figure 10.- Generalized velocity profiles in law-of-the-wall form.



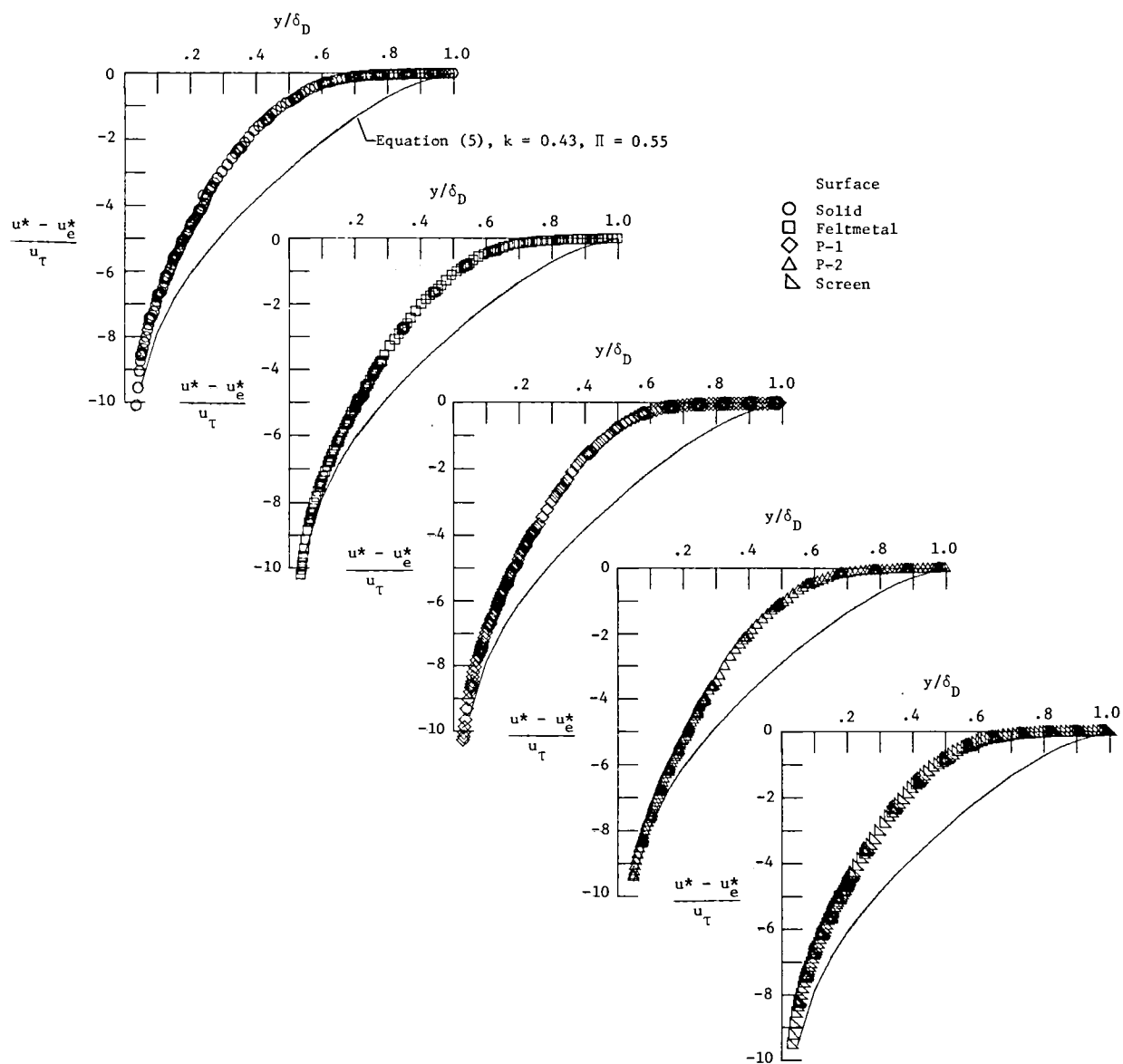
(b) Data at $x = 215.9$ cm.

Figure 10.- Concluded.



(a) Data at $x = 213.4$ cm.

Figure 11.- Generalized velocity profiles in velocity defect form.



(b) Data at $x = 215.9$ cm.

Figure 11.- Concluded.

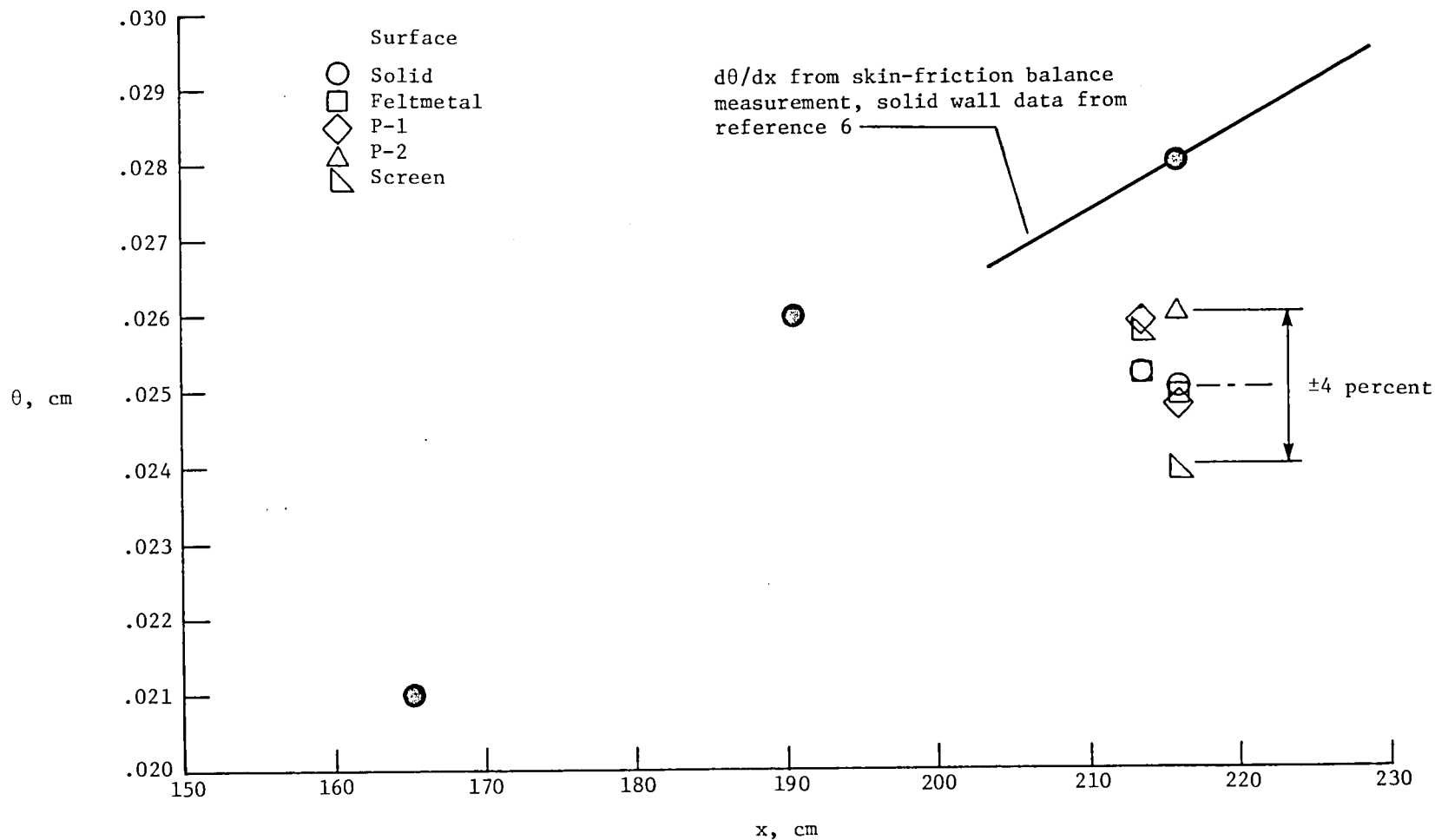


Figure 12.- Measured momentum thicknesses. Solid symbols are data of reference 6 for solid surface.

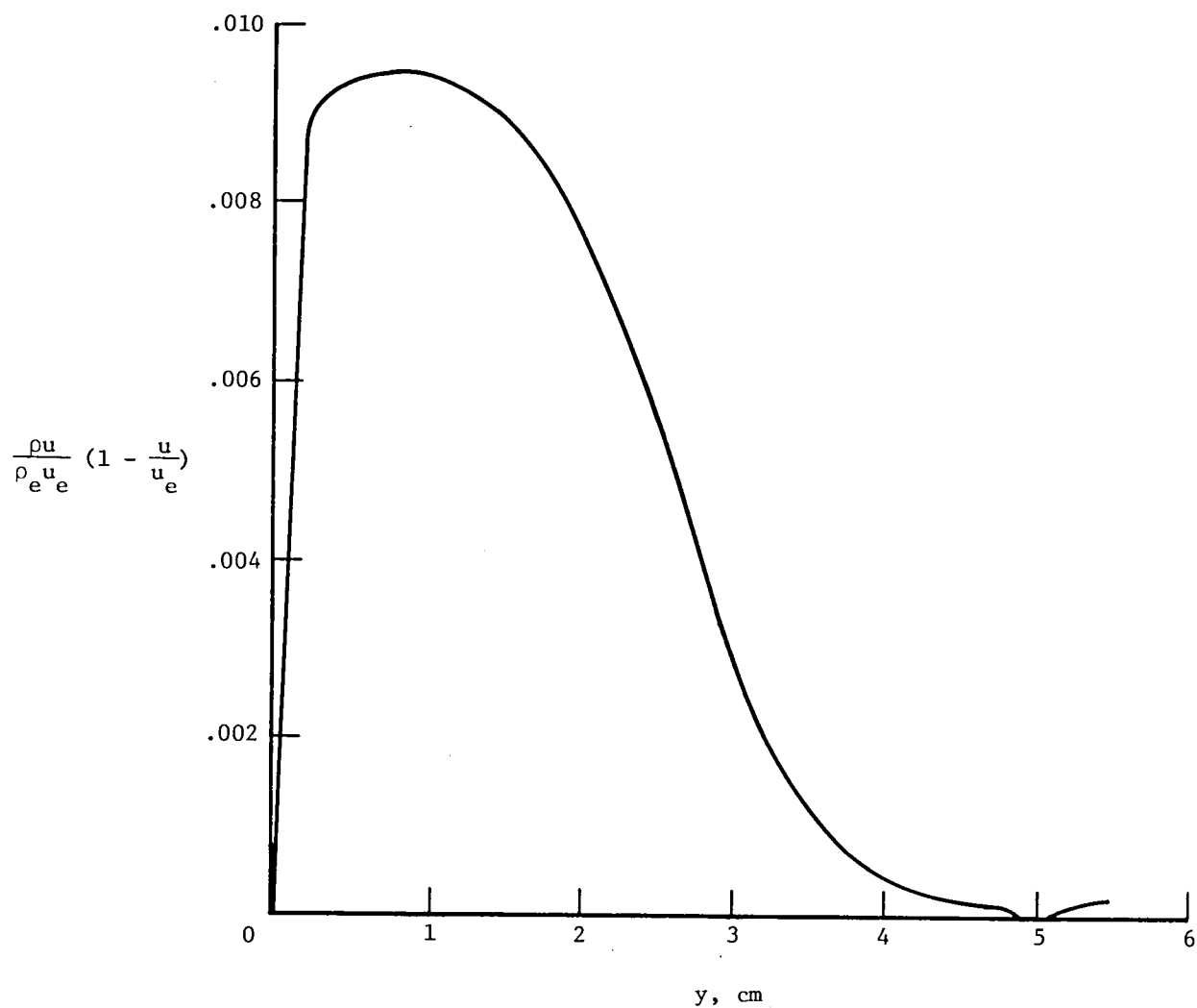


Figure 13.- Typical momentum defect function for runs 7 to 30 on screen surface at $x = 215.9$ cm and $\theta = 0.0258$ cm.

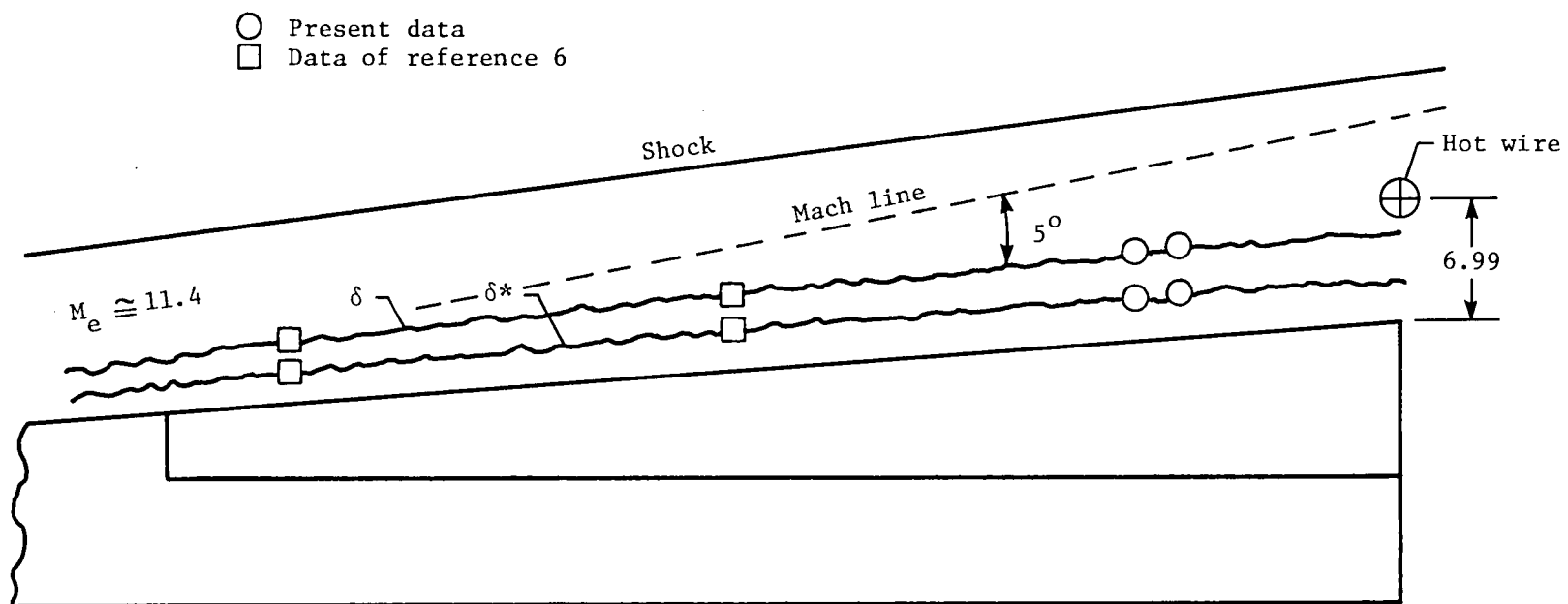


Figure 14.- Location of hot-wire probe.

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16. Abstract An exploratory investigation has been made with four different test surfaces to determine the effect of porous walls on the characteristics of a hypersonic turbulent flat-plate boundary layer. The investigation was an attempt to decrease the surface shear of the boundary layer by transmitting fluctuating pressure energy through the wall and absorbing it in a cavity beneath the wall. Pitot surveys were made at two locations, schlieren photographs of the boundary layer were taken, and hot-wire measurements in the flow above the boundary layer were made to determine whether the surfaces affected the turbulent boundary layer. Neither an increase nor a decrease in surface shear or boundary-layer growth was detected. Tabulations of the pitot data are included.					
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